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PHASE CHANGE THERMAL RADIATOR FLIGHT EXPERIMENT PERFORMANCE AND RESOURCE PLANS

VOLUME I-MANAGEMENT AND TECHNICAL

a plan for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

submitted in response to

PHASE IV REPORT
CONTRACT NO. NAS8-20670

APPROVED BY

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NSL 67-201

SECTION 1.0

MANAGEMENT PLAN

FOREWORD

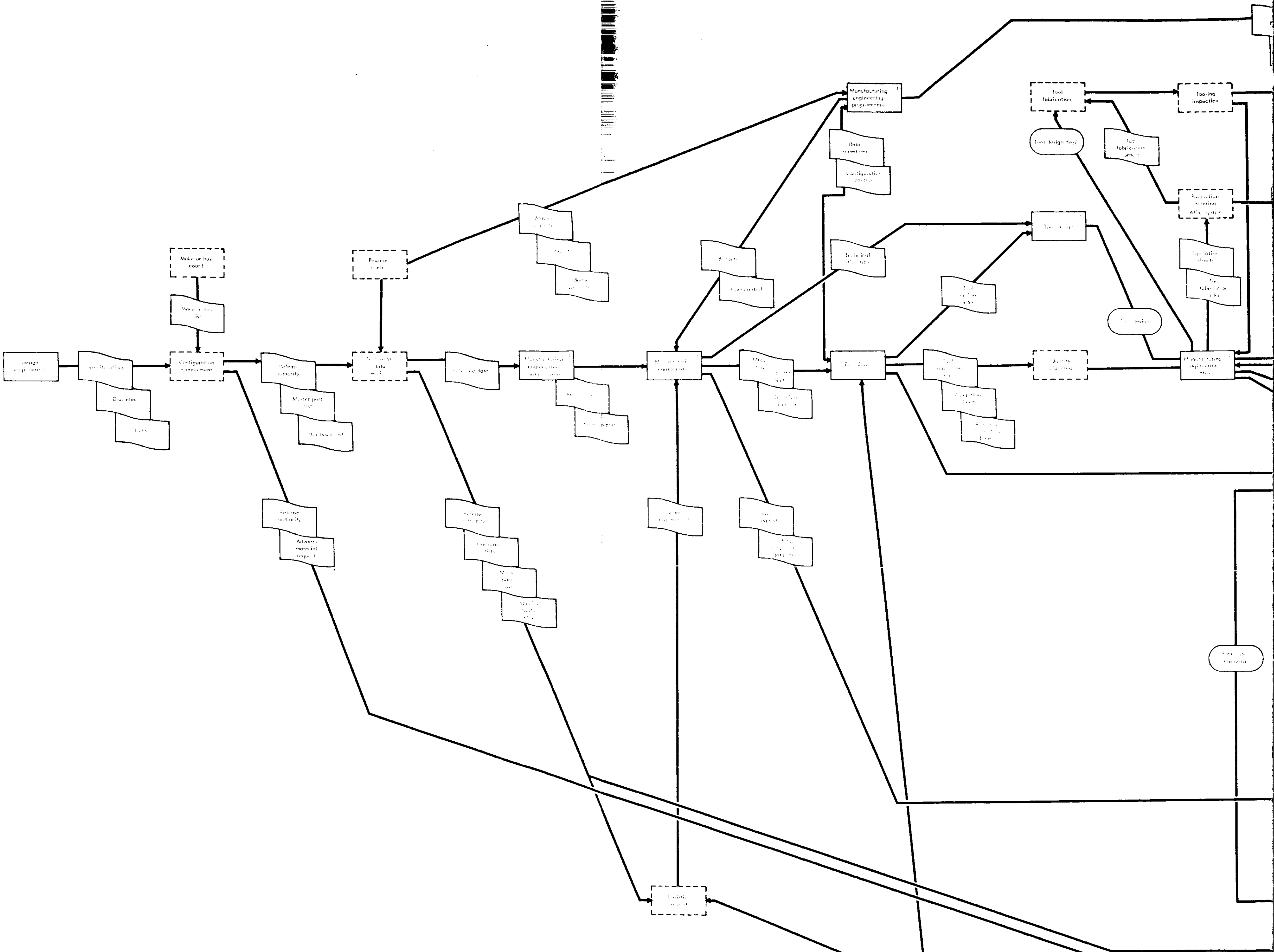
This document describes the procedures and methods that will be utilized by the management segments of the Phase Change Thermal Radiator (PCTR) organization to direct, plan, analyze, evaluate, and report the progress of the PCTR Phase IV Program. It is the primary functional plan for the Program Administration Group of the PCTR section.

The procedures and policies presented in this document were derived from contractually imposed requirements, and supplemented by those of the Northrop Corporation to achieve the program goals. The essential elements of these procedures and policies consist of organizational unit and personnel authority and responsibility definition combined with timely, selected report and review cycles of every major functional, contract end item, and task area. Implementation of these procedures and policies minimizes routine management tasks so that effort is concentrated in those areas of the program which have been shown by the report and review cycles to require attention. With this plan, management control (progress and cost control) of the program is economically and efficiently maintained.

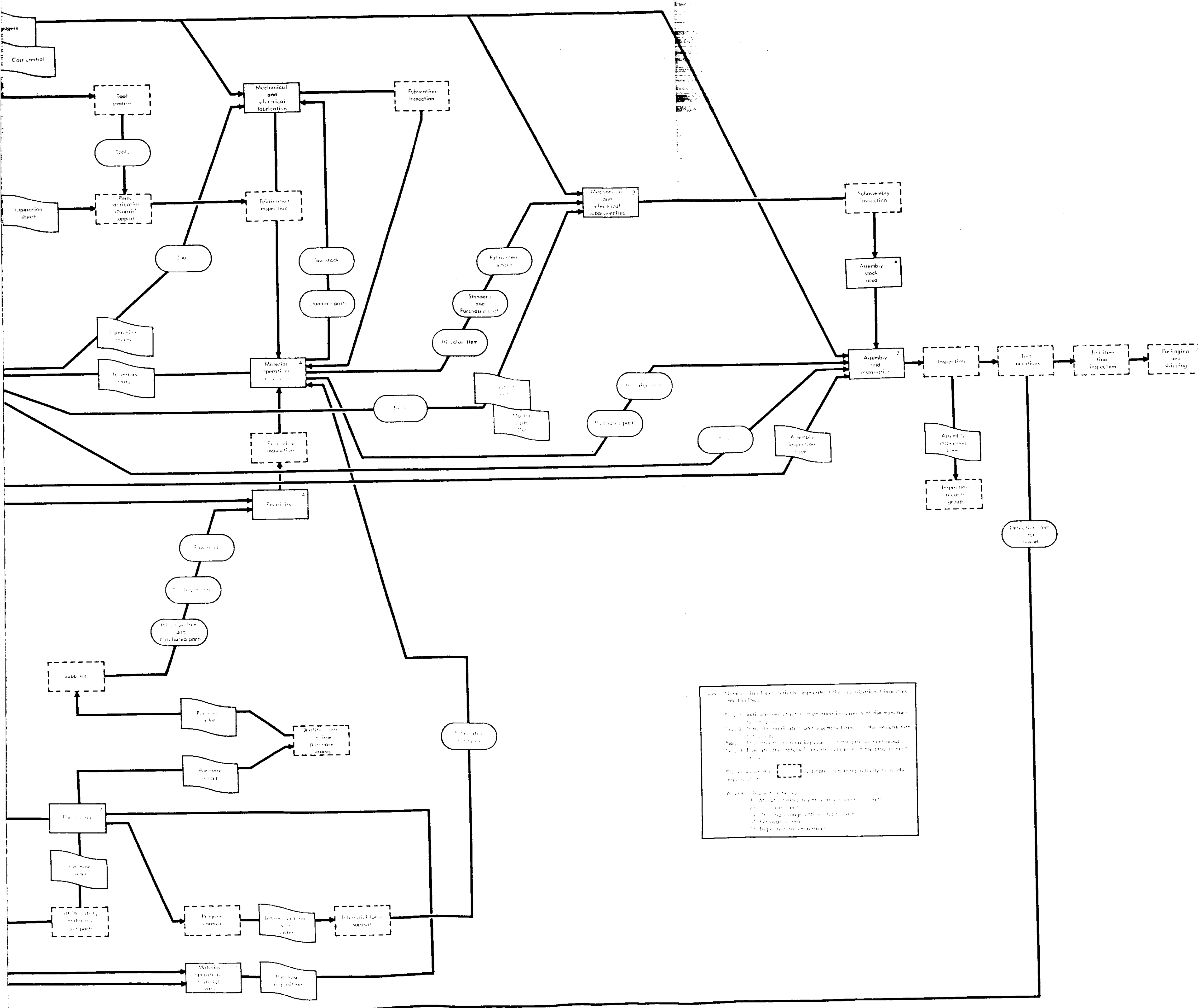
This document contains a section on the Northrop management plan in general, followed by the PERT and Integrated Cost Plan.

As an adjunct to the functional plans and management documents discussed herein, provisions are made for issuance of supplementary directives which are called "Program Directives." These directives shall be collected into the PCTR Program Directive Manual which is a complementary document to this Management Plan. PCTR Program Directives are used to supplement and amplify existing plans and to establish additional procedures whenever the need arises.

OVERALL TABLE OF CONTENTS



OVERALL DOCUMENT FLOW AND FUNCTION INTERFACE DIAGRAM



Cost control
Tool control
Tools
Mechanical and electrical fabrication
Fabrication inspection
Operation sheets
Parts fabrication (floor) support
Raw stock
Standard parts
Material operations
Mechanical and electrical subassemblies
Subassembly inspection
Assembly stock area
Fabricated details
Standard and Purchased parts
Hi value item
Purchased part
Assembly and installation
Inspection
Test operations
End item final inspection
Packaging and shipping
Assembly inspection tags
Inspection records group
Defective item for rework
Receiving inspection
Receiving
Suppliers
Purchase order
Purchasing

TABLE OF CONTENTS

MANAGEMENT PLAN

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 MANAGEMENT PLAN

1.1 PCTR Program Organization and Management

1.1.1 NORTHROP SYSTEMS LABORATORIES STRUCTURE

The Phase Change Thermal Radiator Flight Experiment Program is conducted within the Northrop Systems Laboratories and is organized as an integral section of this organization. The Northrop Systems Laboratories is a major branch of the Nortronics Division which is one of three divisions comprising the Northrop Corporation. The major product areas of this division are aircraft, missiles, and space hardware. The PCTR Program position within the Northrop Systems Laboratories is shown in figure 1-1.

1.1.2 PCTR ORGANIZATION STRUCTURE

The PCTR organization has been arranged into a project type organization with functional line suborganizations to enhance the implementation of control procedures and policies further described in this document. With this organizational structuring, communication lines are shortened between the Program Manager and all elements of the organization.

Figure 1-2 presents the program organization for the Phase IV PCTR. The PCTR organization consists of four line groups. The staffing and level of effort of each group are commensurate with the task loading shown in the Phase IV Cost Proposal. Each of these groups reports directly to the Program Manager.

Each group plans, schedules, coordinates, controls, and directs its efforts in conjunction with other appropriate areas as required for the accomplishment of the area's basic authorities and responsibilities. In order to accomplish these tasks, timely and effective communication of facts and other pertinent information through use of documents, reports, and personel conversation is essential.

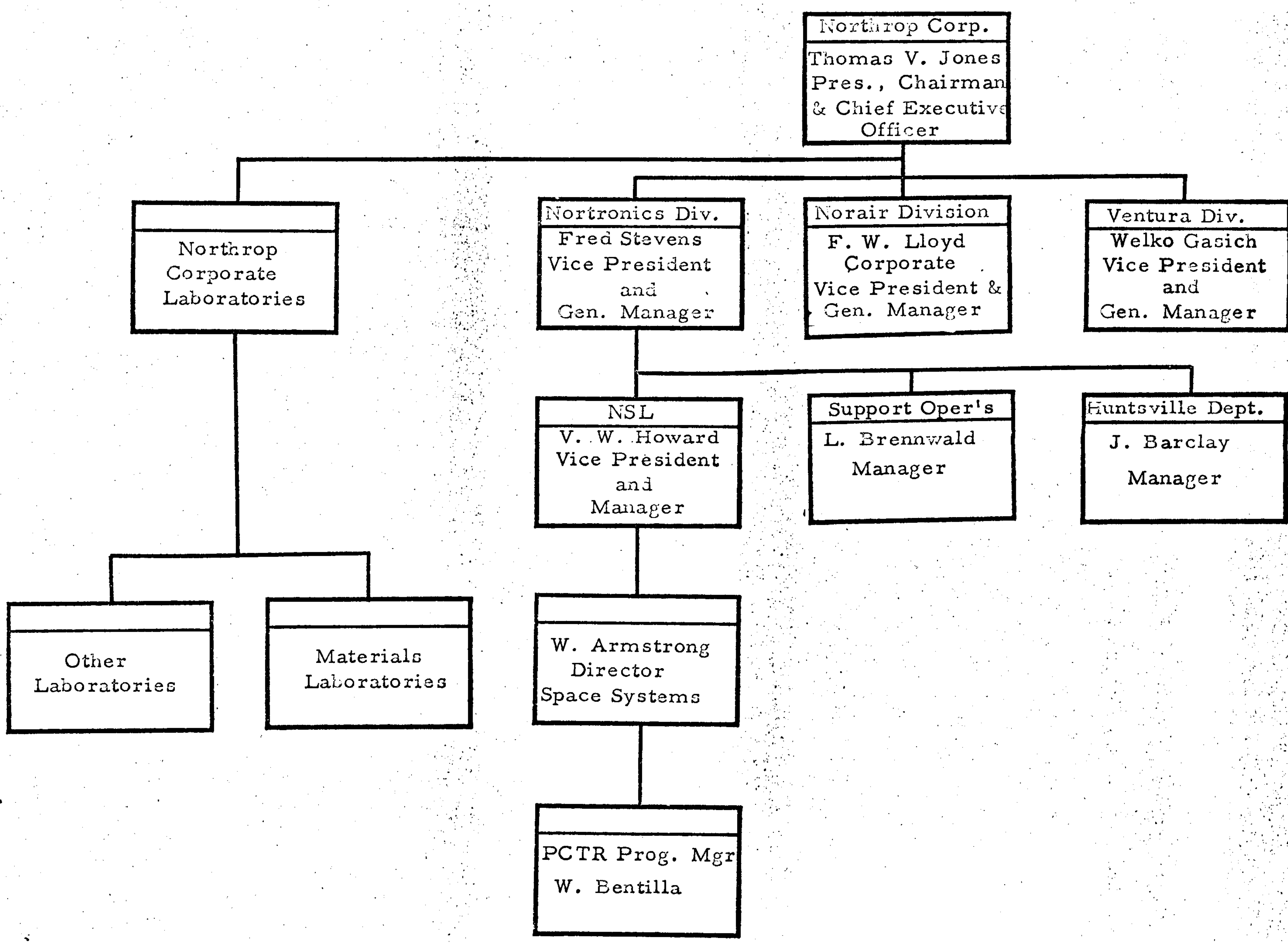


FIGURE 1-1 PCTR PROGRAM POSITION WITHIN NORTHROP SYSTEMS LABORATORIES

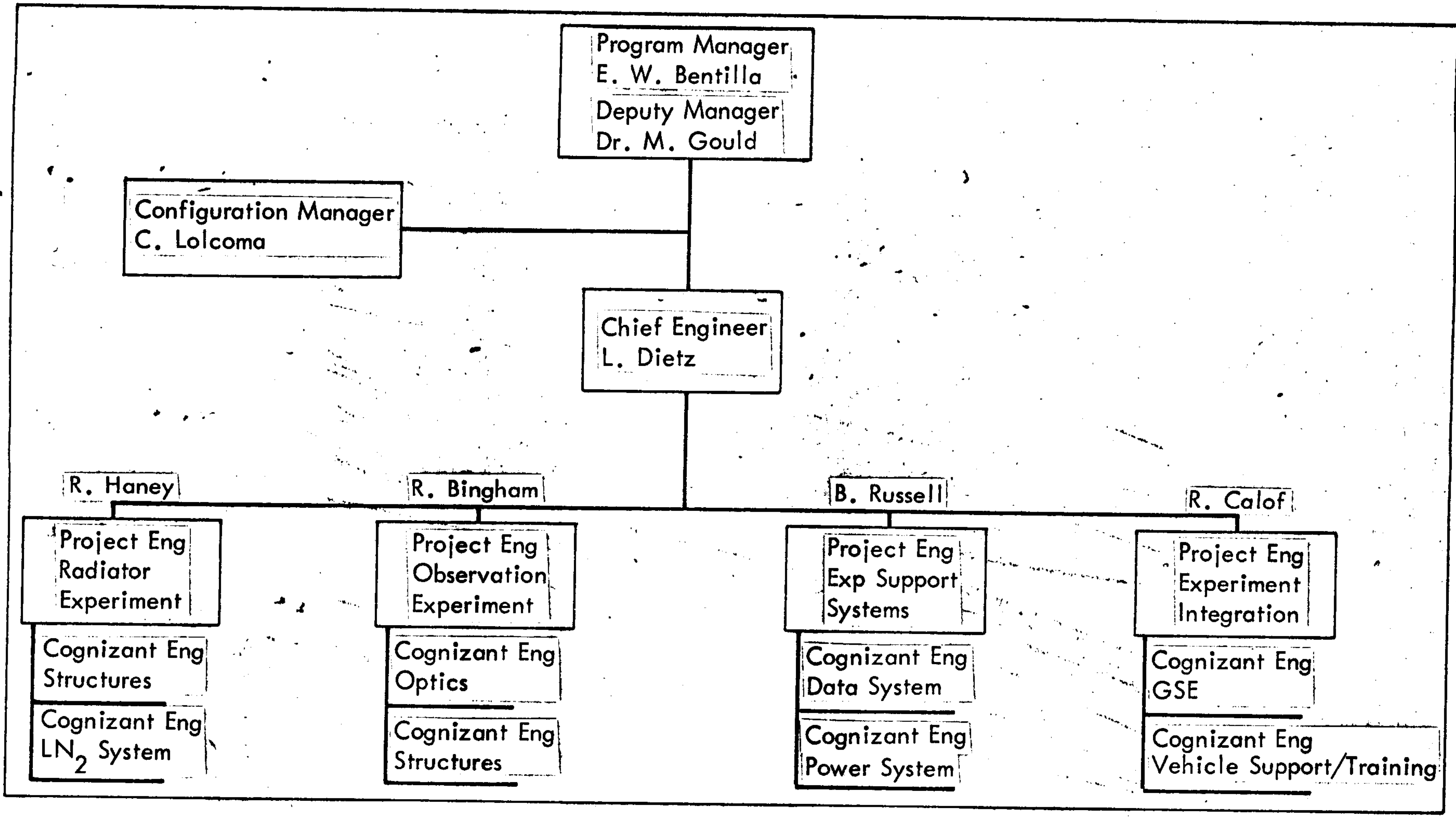


FIGURE 1-2 PCTR PROGRAM PHASE IV DESIGN ORGANIZATION

SE< 3

Implementation of this program is further enhanced by a policy delegating specific authority and responsibility to cognizant engineers within areas of the PCTR Organization. The cognizant engineer is a technical specialist in a particular technology. Within the boundaries of delegated responsibility and contract commitments, he is responsible either for the management of a technical task or for the procurement, design, and development of specific hardware for the PCTR.

1.1.3 PCTR PROGRAM MANAGER

The Program Manager is singularly responsible for complete accomplishment of the tasks contractually required for the PCTR Program. His organization contains all the mechanisms necessary to meet the expected technical, schedule, and cost demands of the program. His authority, which includes complete control of assigned resources and services, is sufficiently extensive to enable him to meet these demands. The Program Manager is responsible to, and has ready access to, Northrop Systems Laboratories management for the effective conduct of his program within contractual requirements. This includes the responsibility to make higher management aware of any need to increase available program resources. By virtue of the Program Manager's assignment, his authority is exercised through the supervisory positions in his organization, and carries strength commensurate with the organization level of these positions. He serves as the single point of authority between the PCTR Program and NASA/MSFC on matters pertaining to technical, schedule, and cost decisions, directions, and management. The Program Manager reports directly to W. Armstrong, Director of Space Systems, who in turn reports directly to Dr. V. W. Howard, Vice President and Manager of Northrop Systems Laboratories. Through this direct communication, top management attention is assured on this program. The Deputy Program Manager assists the Program Manager in all functions as required.

1.1.4 CONTRACT ADMINISTRATION

The Contract Administration Staff section is responsible for:

a) Enforcing contract compliance through periodic meetings with the Program Manager regarding performance, cost, and schedule.

b) Acting as a central point for contract interpretation as to program scope, fiscal funding, legal and regulatory constraints.

c) Supporting the Program Manager in negotiation and contractual liaison with the NASA/MSFC Contracting Officer.

d) Coordinating preparation of formal change proposals.

1.2 PCTR Program Line Functions

The basic authority and responsibility of each of the groups of the PCTR Organization, shown in figure 1-2, is summarized in the following paragraphs. Functional descriptions, authorities, responsibilities, and interrelationships of each organization are covered in detail.

Figure 1-3 depicts the organization of the Program Administration Group. This group has responsibility for:

a) Establishing sales order patterns and cost matrices; issuing work orders and work authorities, issuing and maintaining budgets.

b) Exercising management controls predicated upon management plans, cost plans, schedules, and PERT.

c) Exercising direct working relationship and management authority in configuration control.

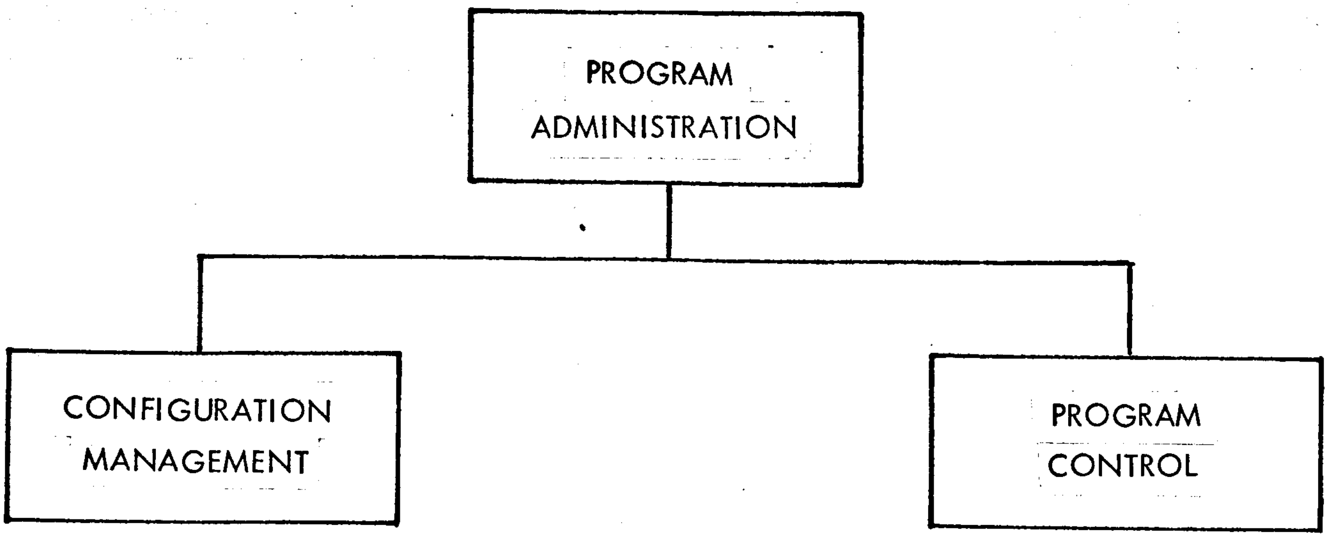


FIGURE 1-3 PROGRAM ADMINISTRATION GROUP

1.2.1 PROGRAM ADMINISTRATION GROUP

- Functional Description

  a) Establish, coordinate, and implement a formal Configuration Review Board (CRB).

  b) Conduct CRB meetings.

  c) Perform drawing check and release functions.

  d) Implement Configuration Management Plan.

e) Organize, coordinate and conduct Preliminary Design Review (PDR), Configuration Design Review (CDR), and Design Engineering Inspection (DEI) reviews and inspections.

f) Release and maintain end item specifications, detail specifications, SCD's, and ICD's.

g) Prepare and process ECP's and SCN's.

h) Provide the PCTR Program with Configuration Management policies and directives.

i) Provide procedures for document identification and part serialization.

j) Maintain data library.

- Interrelationships

The Program Administration Group interfaces with all PCTR Program organizations.

1.2.1.1 <u>Configuration Management Area</u>

Configuration Management has the authority to fulfill the essence and intent of NPC 500-1. This area provides configuration identification, accounting, and control so that all interfaces and requirements are identified, evaluated, and documented. It operates in accordance with the Configuration Management Plan defined in section 1.1.7 of the Management Plan.

1.2.1.2 <u>Program Control Area</u>

The Program Control Area has the authority to implement and coordinate the following: Management Control Plan, Management Plan, Facilities Plan, PERT, and Integrated Cost Plan.

- Functional Description

a) Implement negotiated Phase IV Management Control Plans and Integrated Schedule.

b) Direct maintenance of Functional Plans, Resource Plans, Master Schedules, and Management Plans for Phase IV.

c) Implement and maintain PERT networks and programs, and Integrated Cost Plan for Phase IV.

d) Perform program planning and analysis of Phase IV activities.

e) Prepare schedule and cost status reports.

f) Issue and control budgets.

g) Account for assignment and utilization of personnel, facilities, and equipment.

h) Issue and control work authorizations.

i) Participate in establishment of sales order patterns and cost matrices.

j) Issue program work orders and work authority.

k) Issue and maintain budgets.

l) Maintain resource plans and status for facilities, personnel, and equipment.

m) Analyze and evaluate Cost Expenditure Reports and prepare and maintain Cost Status Charts.

n) Maintain the Integrated Cost Plan.

o) Prepare cost status portion of Management and Customer required reports.

p) Process requisitions for services, personnel, equipment, supplies, and facilities with respect to available budget.

- Authority

The cognizant Program Control Area Supervisor has been delegated full authority to direct the activities defined herein.

- Interrelationships

The Program Control Area, in its assigned functions, interfaces with all organizations of the PCTR Program. This discussion, therefore, covers interfaces of the Program Control Area with organizations outside the program.

1.2.2.1 Chief Engineer

- Functional Description

  a) Establish system and subsystem engineering analysis required to update the PCTR system performance and interface characteristics to satisfy the negotiated Phase IV Master End Item Specification requirements for use on the Engineering Model Design by release and control of PCTR System Engineering Work Authorization.

  b) Establish design engineering activity required to update the PCTR design to satisfy the negotiated Phase IV Master End Item Specification.

  c) Establish system, crew and mission integration tasks required to update the PCTR design operational features and training criteria to be used as a basis for inputs to Systems Engineering and Design Engineering for use on the Engineering Model Design.

  d) Establish engineering task assignments for analyses and design of engineering model test and test apparatus.

  e) Review and approve all specifications.

  f) Conduct design review and analyses to assure no duplication of effort.

  g) Supervise all functions of Systems Engineering and Design; system, crew and mission integration to assure concept compliance and low cost efforts with maximum manpower utilization.

- Authority

  The Chief Engineer has the authority to implement all phases of the Design Plan (NSL 67-203). This authority assures integration of engineering efforts toward the common objective of achieving a low cost PCTR system meeting the requisition of Master End Items (MEI) within the schedule constraints.

1.2.2 ENGINEERING GROUP

Figure 1-4 depicts the organization of the Engineering Group in more detail. This group will perform its tasks in accordance with the Design Plan (NSL 67-203).

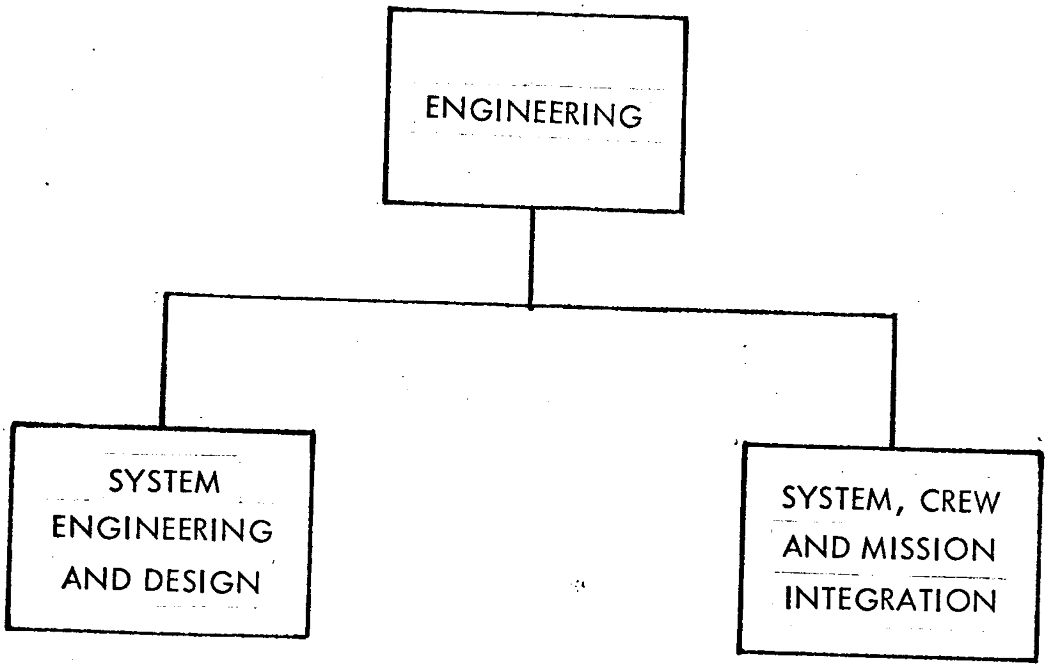


FIGURE 1-4 ENGINEERING GROUP

- Interrelationships
  - a) The Chief Engineer's primary interface is with the Cognizant Engineers from the various areas and with the PCTR Program Manager.
  - b) The Chief Engineer will interface directly with NASA/MSFC technical personnel.

1.2.2.2 System Engineering and Design Areas

- Functional Description

  a) Establish system design criteria and characteristics and define interface criteria.

  b) Accomplish the detail design of the PCTR system and subsystems.

  c) Accomplish detail design of the PCTR handling equipment, shipping containers and protective covers, and sterile containers where necessary.

  d) Prepare technical documentation for design reviews.

  The Tasks required to perform the above are as follows:

  1) Document the results of analyses: Interface Control Documents, Technical Data Reports and Analyses, EMI Test Criteria, Safety Plans and Procedures.

  2) Prepare procurement specifications for all purchased items.

  3) Direct technical efforts of major vendors.

  4) Derive and maintain documentation reflecting system design. This documentation will include technical data reports and analyses.

  5) Maintain Master End Item Specification prepared under Phase III.

- Authority

  a) System Engineering Cognizant Engineer - The supervisor of this area has complete authority for the specification of the overall design criteria of the flight system and the ground system. Where incompatibilities exist at the subsystem level, he has the authority to make decisions at the subsystem level which will assure integration compatibility of the overall PCTR System. He is responsible for the PCTR design meeting the interface constraints and the operational requirements. In exercising this responsibility, he has the authority to define design requirements for each element of the PCTR System.

b) The System Design Cognizant Engineer - The supervisor of this area has complete authority to direct the design and development of the PCTR System and such ground support equipment as may be required to support the system.

- Interrelationships

a) Resolve requirements with System Engineering relative to allowable center of gravity constraints, static and dynamic load constraints, and operational requirements and constraints.

b) Resolve with System Engineering, NASA, and the Apollo Contractor interface requirements plus handling compatibility problems.

c) Assist manufacturing and procurement areas in resolving structural and mechanical questions as required.

d) Establish requirements and evaluate testing conducted by the operations area pertaining to the PCTR system and subsystems.

e) Participate with Reliability and Quality Assurance in establishing and maintaining reliability requirements and quality.

f) Coordinate with Program Administration

1.2.2.3 System, Crew and Mission Integration Area

- **Functional Description**

a) Implement the Technical Integration Plan.

b) Perform total system integration of the PCTR experiments.

c) Perform system integration for three flight articles and backup units.

d) Provide support in systems integration, systems qualification test, and integrated systems test.

e) Monitor and advise on human factors compatibility for crew and systems interfaces in the operation and use of the PCTR system training equipment, mission planning and sequence, etc.

- Authority

The System, Crew and Mission Area is authorized to recommend changes in configuration to the Chief Engineer and Configuration Management.

- Interrelationship

a) This area interfaces with all other technical areas within the program organization.

b) With NASA's coordination, this organization will interface directly with the Apollo Contractor for this definition of interface criteria and constraints between the Apollo and PCTR.

1.2.3 OPERATIONS GROUP

Figure 1-5 depicts the organization of the Operations Group. This group performs its tasks in accordance with the following plans.

a) Make or Buy Plan
b) Test Plan (NSL 67-206)
c) Manufacturing Plan (NSL 67-204).

The Operations Group is responsible for:

a) Procurement and/or manufacturing of hardware.

b) Defining, documenting, and conducting training courses.

c) Planning, conducting, and reporting on all tests conducted at the factory and the operations conducted at KSC as required.

d) Logistic requirements, acceptance data requirements and familiarization manuals and handbooks as required.

The above prime responsibilities are performed by the three areas shown as figure 1-5. The detailed functions of these areas are as follows.

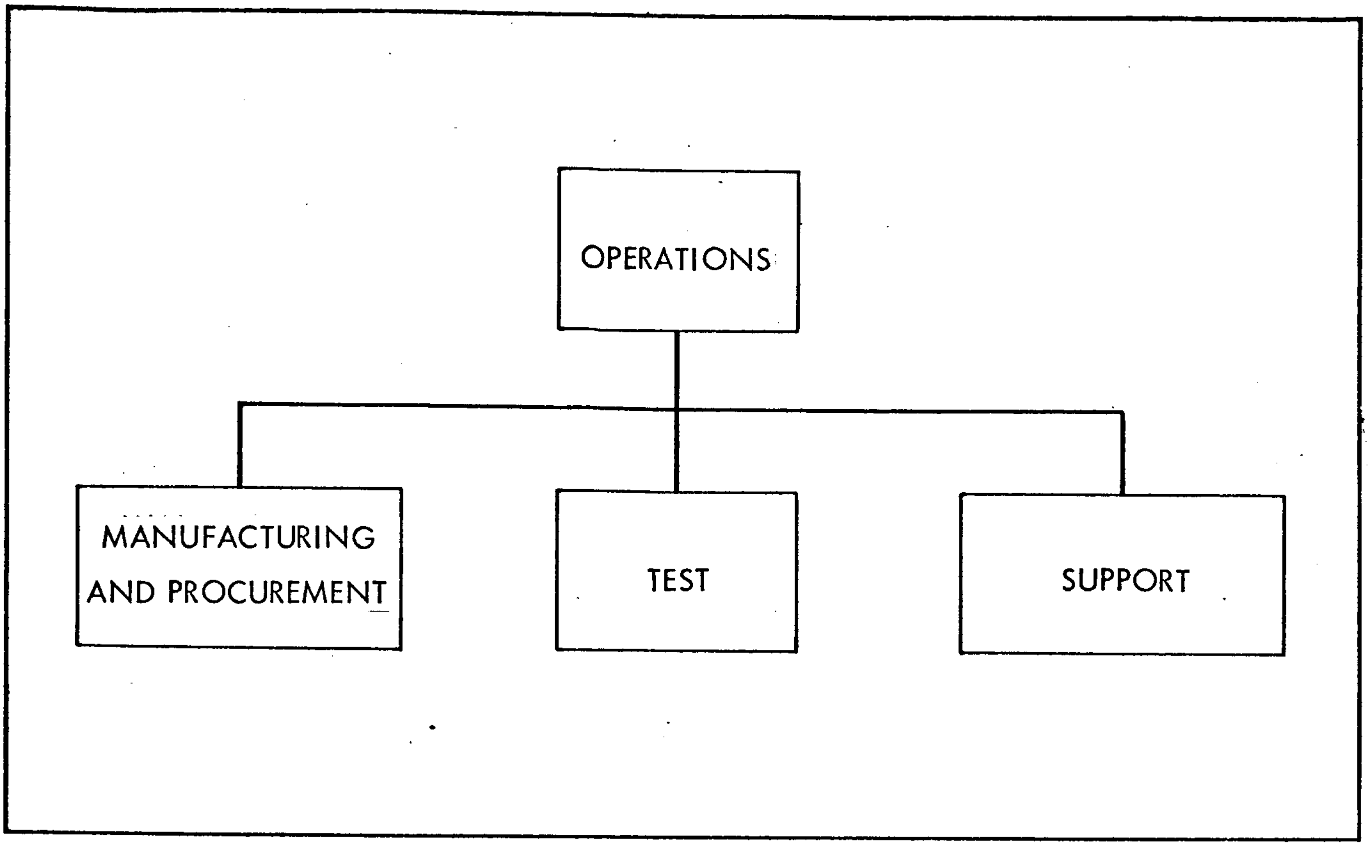


FIGURE 1-5 OPERATIONS GROUP

1.2.3.1 Manufacturing and Procurement Area

- Functional Description

  a) Directs the preparation, control, and maintenance of manufacturing budgets, plans, manloading, and schedules for the PCTR manufacturing program.

  b) Formulates tooling policy and manufactures tools required for the PCTR Program.

  c) Performs the fabrication and assembly required to manufacture all contract end items and in-plant tools and test fixtures.

  d) Maintains a procedure and control system to assure compliance with the configuration control requirements of the PCTR Program.

  e) Prepares and issues status reports on the manufacturing activities in consonance with the PCTR Program Plan.

f) Determines procurement requirements.

g) Performs surveys of suppliers.

h) Procures all PCTR peculiar materials, subcontracts, and services.

i) Maintains active follow-up on all open procurements.

j) Receives, stores, and disburses all product materials.

k) Maintains costed inventory records.

l) Participates in subcontract source selection activities.

- Add contractor cost control procedures where applicable.
- Authority

Manufacturing and Procurement Cognizant Supervisor - The supervisor of this area has complete responsibility and authority for preparation, conduct, and control of the procurement and manufacturing activities of the PCTR program.

- Interrelationships

The Manufacturing and Procurement area, in its assigned functions, interfaces with all operating organizations of the PCTR program. Major interfaces within and outside the PCTR program are as follows.

Organization	Interface
Program Administration	Manufacturing and material cost proposal data inputs; Weekly financial status reports of hours expended.
Contract Administration	Contractual guidance and interpretation; Customer approval of PCTR procurements; Approval of subcontract terms and conditions as applicable to prime contract.
Finance	Purchase order and accounts payable for supplier invoices; Inventory and disbursement information; Inventory information applicable to taxes; Property accountability information.

Organization	Interface
Nortronics Materiel	Process Purchase Orders; Procurement price analysis; Receiving Report initiation; Disbursement of items from common stock; Transportation and shipping program requirements.
Facilities	Plant rearrangement; Office equipment acquisition; Maintenance support.
Other Northrop Divisions	Interdivisional Work Orders for support of PCTR manufacturing requirements, as required.

1.2.3.2 Test Area

- Functional Description

a) Develops Test, Checkout and Operations (TCO) Plans. Provides both short and long range planning on test, checkout and operations activities utilizing Customer-established requirements and Northrop Systems Laboratories needs.

b) Provides for monitoring and reporting on schedule compliance, resolution of conflicts, integration of test, and PERT reporting.

c) Conducts qualification tests on the specimen components and PCTR Qualification System, and submits reports.

d) Conducts preinstallation acceptance tests during assembly. Conducts acceptance checkout of the PCTR flight units. Performs maintenance as specified in the Operating Procedures. Submits reports on all work performed.

e) Performs engineering tests at the direction of the Engineering Group and compiles test results for engineering analysis.

- Authority

Cognizant Test Area Supervisor - The Cognizant Test Area Supervisor has the responsibility to direct the preparation of operating and test procedures.

- Interrelationships

  a) Coordinates with the Support, Manufacturing, Quality Assurance and Reliability, Program Administration and Engineering Areas.

  b) Reports directly to the Operations Group Chief.

1.2.3.3 Support Area

- Functional Description

  a) Derive requirements for and prepare PCTR training Materials such as Familiarization Manual, handbooks as required, etc.

  b) Prepare and conduct PCTR training courses.

  c) Prepare and maintain PCTR Support Plan and schedules.

  d) Be responsible for the Acceptance Data Package to be shipped with each flight article.

- Authority

  Cognizant Support Area Supervisor - The Cognizant Support Area Supervisor has the authority and responsibility to direct the activities of Support Area personnel in fulfilling the requirements delineated herein and as outlined in the Logistics Plan.

- Interrelationships

  a) The Support Area will interface with the Engineering Area to specify, direct, and develop training equipment.

  b) Participate in design reviews.

  c) Coordinate with Test Area personnel.

  d) Coordinate with Quality Control Area personnel.

  e) Interface with Program Administration on scheduling and planned support and operations.

  f) Report directly to the Operations Group Chief.

1.2.4 QUALITY ASSURANCE, RELIABILITY AND SAFETY GROUP

This group is responsible for assuring the Program Manager, Northrop Management, and other appropriate parties that the PCTR system is of acceptable quality and reliability; establishing PCTR system reliability requirements and directing reliability programs to assure satisfaction of these requirements; and coordinating with customer representatives on all quality matters.

Figure 1-6 depicts the organizational structure of the Quality Assurance, Reliability and Safety Group. This group performs its task in accordance with the Quality Assurance, Reliability and Safety Plan (QAR&S).

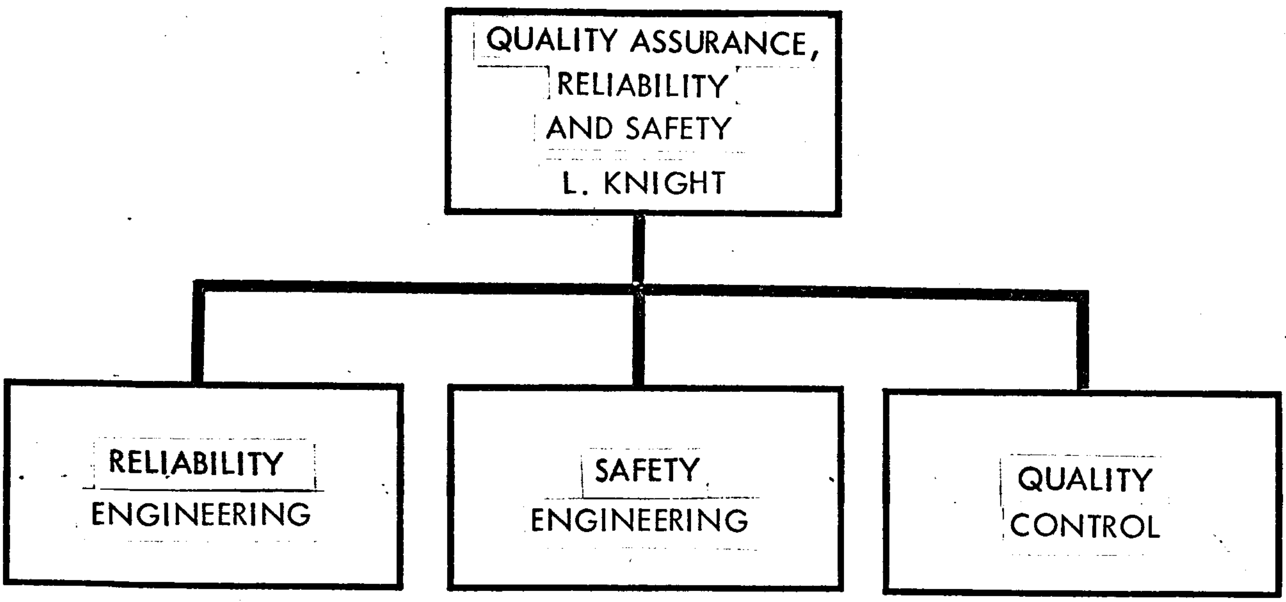


FIGURE 1-6 QUALITY ASSURANCE, RELIABILITY AND SAFETY GROUP

This group has the responsibility for:

a) Implementing Phase IV Reliability Program Plans
b) Implementing Phase IV Quality Program Plans
c) Implementing Phase IV Safety Program Plans.

1.2.4.1 Reliability Engineering Area

- Functional Description

a) Provide detail design reliability requirements at all levels of design and predict inherent design reliability during development.

b) Perform Failure Mode, Effect, and Criticality Analyses (FMECA) at all levels of design.

c) Provide standardization of Design Practices guidelines to design groups.

d) Participate in design reviews.

e) Prepare and maintain an Acceptable Parts List.

f) Establish and maintain a Parts Selection Criteria.

g) Prepare Supplier Control Procedure.

h) Prepare and maintain Parts Testing Requirements and Methods.

i) Perform diagnostic analyses of failed parts and materials.

j) Develop, maintain, and implement an Evaluation Program.

k) As part of Evaluation Plan, develop Reliability Assessment Procedure.

l) Perform Reliability Verification of PCTR system hardware.

m) Analyze hardware failures and correction taken for maintaining system inherent design reliability and notifying NASA of failures during qualification testing.

- Authority

The Reliability Engineering Area Cognizant Engineer has full authority to implement and conduct a reliability program as defined in the QAR&S.

- Interrelationships

The Reliability group interfaces with the following PCTR Program organizations.

Organization	Interface
Engineering	Provide detail design information for reliability analyses; Provide reliability allocations; Design review; Provide part and material selection and performance criteria; Provide assistance in evaluating reliability assessment.
Procurement	Provide reliability prediction of design to assist suppliers in deriving PCTR system predicted reliability value.
Test, Checkout and Operations	Provide qualification test results for assessing reliability of system.
Quality Control	Provide Failure and Correction Taken (FACT) forms.

1.2.4.2 Quality Control Area

- **Functional Description**

  a) Implement negotiated Phase IV Quality Program Plan of the QAR&S Plans.

  b) Perform quality planning function in design development phase.

  c) Develop process control plans.

  d) Perform procurement control functions.

  e) Prepare quality data and documentation in accordance with requirements of Quality Program section.

  f) Maintain failure reporting and corrective action system.

  g) Perform inspection of incoming product, tooling, fabrication, assembly and test of PCTR equipment to engineering drawings and specifications.

h) Maintain PCTR Assembly Inspection Books.

i) Perform Materials Review function.

j) Maintain calibration control of inspection, measuring, and test equipment.

k) Participate in preparation of PCTR fabrication and assembly plans.

l) Audit completed inspection records and prepare Acceptance Data Packages.

m) Establish and implement quality audit function (systems audits).

n) Perform purchase order review on a predetermined basis.

- Authority

The Quality Control Area Cognizant Engineer has full authority to implement the plans and direct the Quality Control functions as outlined herein and defined in the Quality Program section.

- Interrelationships

The Quality Control Unit interfaces with the following PCTR Program organizations:

Organization	Interface
Configuration Management	Change Board activities; Drawing and specification reviews; Contract changes.
Program Administration	Scheduling; Program budget coordination.
Engineering	Drawing and specification reviews; Failure Reports.
Test, Checkout and Operations	Test Plan coordination; Test verification.
Manufacturing and Procurement	Supplier evaluation and selection; Supplier surveys; Incoming product evaluation.
Reliability Engineering	Failure Reports and evaluations.

1.2.4.3 Safety Assurance Area

- Functional Description

  a) Implement negotiated Safety Assurance Plan of the QAR&S Plan.

  b) Perform astronaut safety planning function in the design phase.

  c) Develop Safety Requirement for all equipment items interfacing with astronaut.

  d) Perform inspection of all equipment for compliance with safety.

  e) Review all astronaut participation in PCTR experiments for safety compliance and recommended changes where safety would be improved.

  f) Contribute safety considerations to training instructions for astronauts and ground personnel where required.

- Authority

  The Astronaut Safety Engineer has full authority to implement the plans and direct the functions outlined herein and defined in the Safety Program section.

- Interrelationships

  The Safety Assurance Unit interfaces with the following PCTR Program organizations:

Organization	Interface
Configuration Management	Review of configuration for astronaut safety.
Engineering	Drawing and specification reviews for astronaut safety.
Test, Checkout and Operations	Test Plan coordination for astronaut safety; also ground crew..
Reliability and Quality Assurance Engineers	Review Failure Reports and evaluation from viewpoint of astronaut safety.

1.3 Management Plans

1.3.1 MANAGEMENT CONTROL SYSTEM

The Phase Change Thermal Radiator Program Manager, in his direction of the Phase IV Program, will be aided by Northrop Systems Laboratories Management Control System which is described herein. This Management Control System is the tool which Program Administration provides the Program Manager giving him visibility of program, schedule, and cost status.

1.3.1.1 Management Documents - Order of Precedence

The order of precedence of management documents in the Northrop Systems Laboratories' Management Control System as it applied to the PCTR Program is as follows.

a) The Phase IV Contract
b) Contract Exhibit A - Statement of Work
c) Contract Exhibit B - PCTR Specification
d) Northrop Sales Order 7XXX-XXXX
e) Management Plan - NSL 67-201
f) Management Control Plan - NSL
g) PERT and Integrated Cost Plan - NSL

1.3.1.2 Interrelationship of Management Documents

Figure 1-7 depicts the interrelationship of management documents and functional plans, indicating the flow of data during the preparation phase of these documents. This same interrelationship prevails during the use and maintenance phase of the documents. It should be noted that the Management Control Plans are the focal point of the management documentation.

1.3.1.3 Management Control Plans

Management Control Plans (NSL 67-201) are a sequential, narrative, and graphic presentation of the tasks, schedules, and costs for performing the

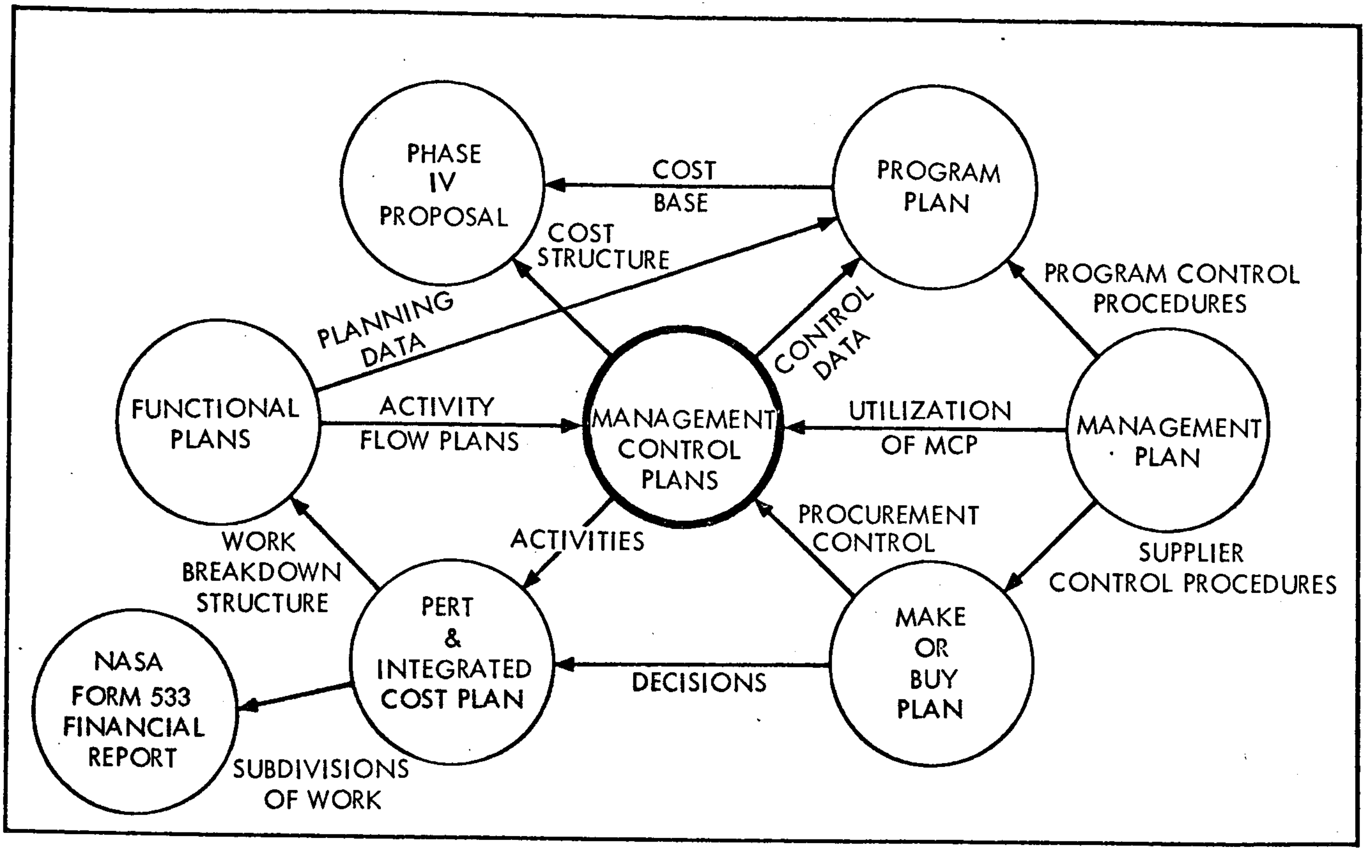


FIGURE 1-7 INTERRELATION OF MANAGEMENT AND FUNCTIONAL PLANS

Phase IV PCTR Program. There are Management Control Plans for each organizational element of Northrop Systems Laboratories' PCTR organizations.

The MCP format consists of a one-page presentation, as shown in Figure 1-8, which contain the task descriptions for a previous NSL program. A separate integrated schedule sheet depicts schedule date for the subtasks to be performed by an organizational element for an indicated subdivision of work.

The numbering system for the MCP provides a means for sorting such that the various tasks and subtasks can be segregated either by the Work Breakdown Structure (Contract End Items) or by organization. This two-way sort permits two types of Management Control Plans to be collated and used for management control in two dimensions as follows.

a) Contract End Item Control

A numerical sort of MCP's by Contract End Items, subdivisions of work subsystems, and functional tasks provides a sequential listing of tasks and subtasks that is used by cognizant engineers to manage the activities of

NORTHROP SPACE LABORATORIES ALSD – MANAGEMENT CONTROL PLAN

CONTRACT END ITEM Qualification Model -2000	GROUP Engineering
SUBDIVISION OF WORK Drill Subsystem -2300	CHIEF S.O. Bresin — NO. 1
TASK AREA Subsystem Design Tasks -2322	PREPARED BY D. Ross
AREA System Design 2572-1	MCP SCHEDULE CHART: 2572-1-1

PERT NET (TASK) NO.	PERT ACTIVITY (SUB-TASK) NO.	DESCRIPTION
	001	TITLE: Energy Conversion Drawings and Specifications Produce updated drawings and specifications to reflect data obtained in previous constraining tasks. This includes fabrication drawings for the drill energy conversion mechanism and drawings and specifications for vendor designed and fabricated items. PREVIOUS CONSTRAINING TASKS 3222-001 TASK PRODUCT Detailed fabrication drawings and specifications SUBSEQUENT USE Procurement and fabrication
	002	TITLE: Drill String and Bit Drawings and Specs Produce updated drawings and specifications to reflect data obtained in previous constraining tasks. This includes drawings and specifications for the fabrication or purchase of drill string extensions, drill bits , bit container. PREVIOUS CONSTRAINING TASKS 3222-002 and 3222-003 TASK PRODUCT Detailed fabrication drawings and specifications SUBSEQUENT USE Procurement and fabrication
	003	TITLE: Interface Control Document Preparation Produce updated Interface Control Documents in coordination with NASA/MSC and interfacing contractors. PREVIOUS CONSTRAINING TASKS 3222-004 TASK PRODUCT Detailed drawings and specifications SUBSEQUENT USE ALSD interface control

FIGURE 1-8 MANAGEMENT CONTROL PLAN FORMAT

all organizations in designing, manufacturing, testing, and delivery of the equipment for which they have cognizance. A complete numerical sort by Contract End Item is used by the Program Control Area to monitor the activities of all organizations to provide the Program Manager with program status against the CEI MCP as a baseline.

b) Organization Control

A numerical sort of the MCP's by organization yields a sequential listing of tasks and subtasks to be used by organization chiefs and supervisors as a baseline for control of their day-to-day work assignments and plan for expenditure of their budget resources.

1.3.2 PROGRAM ADMINISTRATION

Program Administration, in this support of the Program Manager, utilizes the Northrop Systems Laboratories Management Control System described above to provide work, schedule, and cost status and control of the Phase Change Thermal Radiator Phase IV Program against the Management Control Plan as a baseline.

1.3.2.1 Work and Schedule Control

Table 1-1 lists the Functional Plans which detail methodologies utilized by organizations for accomplishing the Phase IV PCTR Program. Based on these plans, each organization has derived a listing of discrete tasks or activities that they perform in relation to the end items to be delivered under the Phase IV Contract. These discrete tasks are listed in the Management Control Plan for each organization and will be included on the PERT network that is companion to the MCP's.

TABLE 1-1 FUNCTIONAL PLANS AND USING ORGANIZATIONS

	Plan	
NSL 67-201	Management Plan	Program Administration Group
NSL 67-202	Technical Integration Plan	Configuration Management Area
NSL 67-203	Design Plan	Engineering Group
NSL 67-204	Manufacturing Plan	Operations Group
NSL 67-205 (1)	Quality Control Plan	Quality Control Area
NSL 67-205 (2)	Reliability Plan	Reliability Area
NSL 67-205 (3)	Safety Plan	Operations Group
NSL 67-206	Test Plan	Operations Group
NSL 67-207	Facilities Plan	Program Administration Group
NSL 67-208	Logistics Plan	Operations Group
NSL 67-210	Schedule Plan	Program Administration Group

Table 1-2 is the Work Breakdown Structure of the Phase IV Program which is based on the Contract Statement of Work and the deliverable items of the contract. The numbering system applied to the work breakdown structure corresponds to the last four digits of the eight-digit numbers used in Northrop Systems Laboratories' Sales Order System. These last four numbers of the sales order number are also used to number the networks of the PERT system. A detailed description of the numbering system is contained in the PERT and Integrated Cost Plan contained herein.

TABLE 1-2 WORK BREAKDOWN STRUCTURE

ORGANIZATIONAL MANAGEMENT CONTROL PLANS

7220	Program Administration
7230	Engineering
7240	Operations
7250	Quality Assurance, Reliability and Safety

CONTRACT END ITEM MANAGEMENT CONTROL PLANS

1000	Prototype Unit
2000	Qualification Unit
3000	1st Flight Unit
4000	2nd Flight Unit
5000	Ground Support Equipment
6000	Training
7000	Mangement and Documentation

WORK BREAKDOWN STRUCTURE (Subdivision of Work)

1000	Prototype Unit
1100	Radiator Experiments
1200	Observation Experiment
1300	Support Systems
1400	Systems Integration
2000	Qualification Unit
2100	Radiator Experiments
2200	Observation Experiment
2300	Support Systems
2400	Systems Integration
3000	1st Flight Unit
3100	Radiator Experiments
3200	Observation Experiment
3300	Support Systems
3400	Systems Integration
4000	2nd Flight Unit
4100	Radiator Experiments
4200	Observation Experiment
4300	Support Systems
4400	Systems Integration

TABLE 1-2 (continued)

WORK BREAKDOWN STRUCTURE (Subdivision of Work) - (continued)

5000	Ground Support Equipment
5100	Checkout Console
5200	Battery Support Unit
5300	LN_2 Fill System
6000	Training
7000	Management and Documentation
7100	Program Administration
7200	Engineering
7300	Operations
7400	Quality Assurance, Reliability and Safety

FUNCTIONAL TASK AREAS

XX00	Program Administration
XX10	Systems Engineering
XX20	Design Engineering
XX30	Manufacturing
XX40	Test and Operations
XX50	Quality Assurance
XX60	Reliability Engineering
XX70	Safety Engineering
XX80	Support Operations

1.3.3 PROGRAM DOCUMENTATION

PCTR Program Administration is the central agency for the administration, control and submittal of all PCTR contractually required data.

1.1.3.1 NASA/Contractor Management Review Meetings

The preparation of reports to be given at monthly meetings will be coordinated by the Program Administration Group. All elements of the report will be obtained from the cognizant organizations and incorporated into the submittal document.

Individuals will be assigned specific responsibilities for each action required to prepare for the monthly meeting and to preface the minutes of the various work meetings. These individual elements will be incorporated into the submittal documents by a program documentation representative. All submittals will be reviewed and approved by the Program Manager or his representative.

1.3.3.2 Final Report

The preparation and submittal of the Final Report will be handled in essentially the same manner as described in 1.3.3.

1.3.3.3 Documentation Control

All documents appearing on the Document Requirements List (DRL) will be identified, controlled, and maintained. The documents submitted for approval of the DRL are schedule and cost monitored under the administrative authority of the PCTR Program Administration Group.

The assignment of document indentification numbers is made by the Release Desk, an element of the Configuration Management Area. A number is assigned to a document upon receipt by the Release Desk of a Document Request and Release Form (DRR) from the organization responsible for preparing the document, or change to that document.

1.3.3.4 Document Maintenance

Document maintenance includes: (1) Document Storage, (2) Release Control, and (3) Change Accountability.

1.3.3.4.1 DOCUMENT STORAGE -- Northrop Systems Laboratories Technical Data Services Group is the sole custodian of all document originals. The document originals are stored in locked cabinets with limited access by authorized personnel.

1.3.3.4.2 RELEASE CONTROL -- No document originals, or any part thereof, may be withdrawn without submitting to the Release Desk a Document Request and

Release Form (DRR) signed by the Program Manager or his designated alternate with a written explanation of why the original is being withdrawn.

A Chargeout Card replaces a withdrawn original and the DRR form is filed for record. The same rule applies to additional copies.

If a request for additional copies is received from NASA or required by Northrop, an authorized DRR must be submitted to the Release Desk.

1.3.3.4 CHANGE ACCOUNTABILITY -- Document change accounting will be accomplished by maintaining a Document Identification Index. This index is the responsibility of the Configuration Management Area and is prepared for use by NASA. A section of this index contains Supplier Documents. There is a separate page for each document. The index is updated immediately as each original document is released and as a document is reissued or changed. As each document is submitted to Configuration Management for release, reissue, or change, this office will compare the Document Identification Index with the information presented on the Document Request and Release Form.

As previously stated, the Configuration Management Office is the last authority to approve documents prior to release.

When a document is submitted for release approval, Configuration Management checks the index for the last issue of that document. If the previous issue of that document does not immediately precede the new issue, the new issue will be withheld until a proper determination is made.

1.3.3.5 Configuration Management Documentation

Identification, release, control and maintenance of End Item and Detail Specification, Interface Control Documents, and Design and Procurement Drawings are managed by the Configuration Management Procedures submitted to NASA.

1.3.3.6 Supplier Document Administration

When required, each Northrop Systems Laboratories Procurement Order to a supplier contains Data Items. Northrop provides suppliers with the proper content and format for each document required and a schedule of submittal to

Northrop. Northrop exercises positive change control over documents required from suppliers. Documents delivered by suppliers are entered on the Document Identification Index which is maintained by the Configuration Management Office. Northrop Systems Laboratories reserves the right to approve or disapprove supplier documents required by Northrop Systems Laboratories Procurement Orders. Supplier documents, except proprietary data, delivered to Northrop Systems Laboratories will be available to NASA upon request.

1.3.3.7 Submittal and Acceptance

When a Type I document is released for NASA approval, the title page of the approval copy will be stamped, "Preliminary-NASA, Approval Pending." If approved, or if 20 calendar days have elapsed, Configuration Management notes the approval on the Document Identification Index and authorizes formal release of the document. The reproduced copies will be stamped, "Approved by NASA." Program Administration is responsible for transmittal of the documents to NASA.

1.3.3.8 Supporting Organizations

The PCTR documentation function is supported by separate Northrop Systems Laboratories organizations outside the PCTR, as shown in figure 1-9.

Procedures defining the method by which Northrop Systems Laboratories will manage Supplier Contracts and Supplier Documentations are submitted to NASA at the end of Phase IV.

1.4 Procurement Management

The PCTR Program utilizes Nortronics Procurement organization which is staffed with personnel skilled in the areas of negotiation, pricing, and cost analysis, and having a thorough knowledge of PCTR and related Government regulations. From the point of submittal of the Phase IV Proposal, interface is maintained with the key selected or potential suppliers. Work proceeds during the holding period to firm up statements of work, implement any changes that result during this period, and assess the effect on cost, schedule, and performance. Concurrently, negotiations with the selected long lead high value

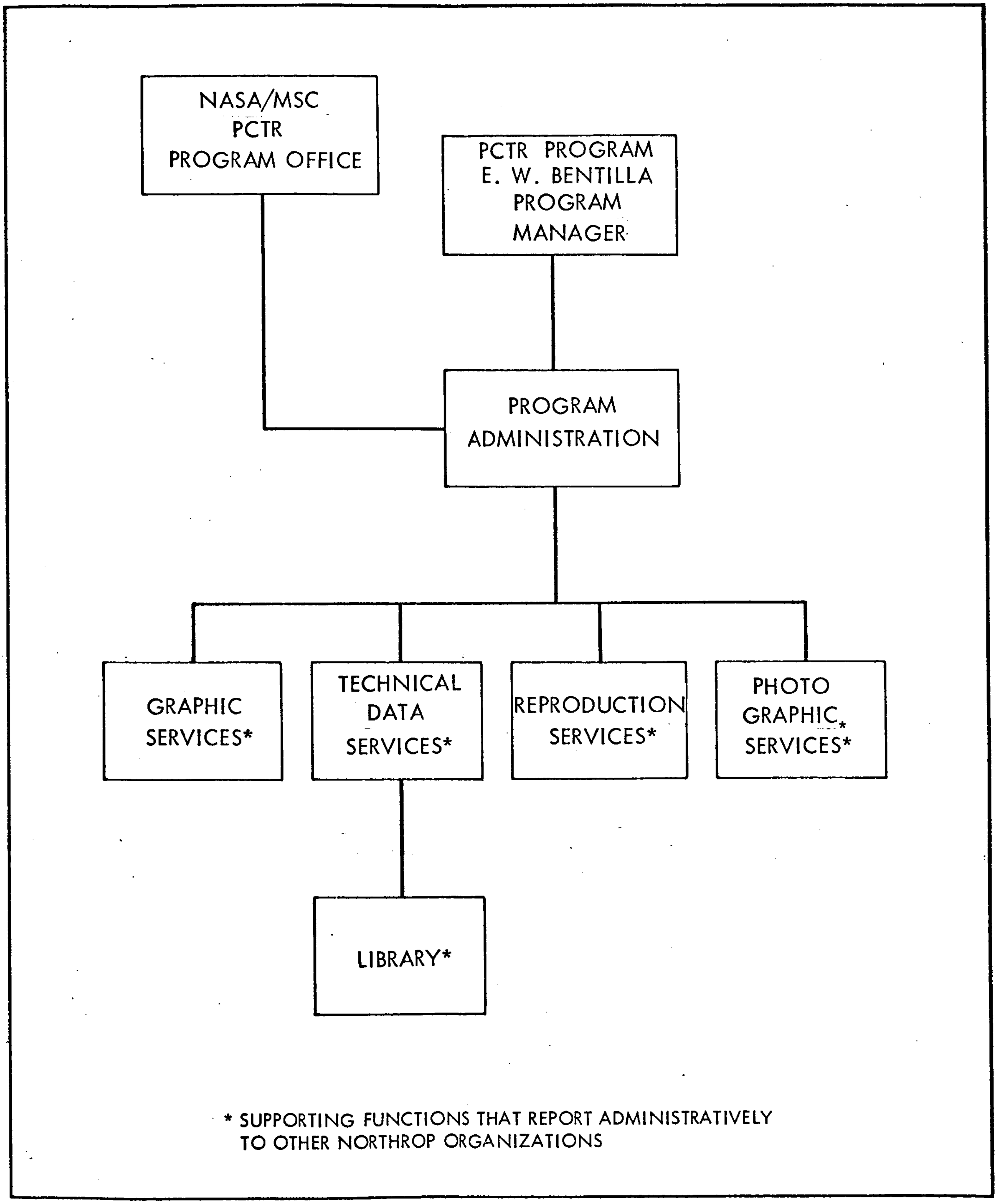


FIGURE 1-9 PCTR PROGRAM ORGANIZATION DOCUMENTATION SUPPORT

suppliers concerning such matters as terms and conditions, data submittal, hardware delivery schedules, any field support requirements, etc., are being finalized. This effort permits implementation of critical procurements within one month after prime contract go-ahead.

Procurement Management plans, schedules, coordinates, controls, and directs the combined efforts of the supplier and the Nortronics purchasing with the PCTR Operations Group. Procurement management extends from the time that proposal efforts are initiated through the performance of the contracted efforts and the final closeout of the records. The purpose is to assure that all phases of the supplier's document efforts are compatible with NASA's objectives regarding technical performance, schedule performance, quality, documentation and cost.

All suppliers are required to maintain effective configuration management and to support Northrop Systems Laboratories in an overall NPC 500-1 Configuration Management Program.

1.4.1 HIGH VALUE/LOW VALUE/LONG LEAD CONCEPTS

PCTR Program procurement personnel apply the concept of High Value/Low Value to all procurement activities; i.e., plan and schedule actions required commensurate with the relative value of the items involved. Through cost reduction efforts are applied to High Value items to accomplish the attainment of desired performance and reliability by considering such factors as:

a) Depth of completion to be solicited.
b) Level of specialized supplier capability needed.
c) Potential second-source selection
d) Extent of flow time required.
e) Priority of internal handling.

Target pricing techniques are used in this type of procurement where the purchase authority is routed through an estimating and budgeting function to establish a reasonable target price for the buyer to meet. This target is established by referring to past history records of similar procurements from previous contracts which are maintained in the central purchasing function. Large aberrations from the target price must be approved by supervision to placement of the order.

1.4.2 STATUS REPORTING

Each High Value item is scheduled individually for all significant events which must be accomplished to effect on-time delivery of the item. The buyer is responsible for updating the actual performance of delivery schedules. Weekly reviews are held by the Procurement Area on status of all High Value items. At this time, program aberrations are discussed and direction given as to corrective action to be taken.

1.4.3 SMALL BUSINESS AND LABOR SURPLUS UTILIZATION

Prior to bid solicitation, buyer personnel carefully consider the feasibility of classifying components for small business competition, and purchase these or other parts from suppliers located on areas classified by the Department of Labor as labor surplus regions. Coordination of both small business and depressed area procurements are maintained with the Inspector, Air Force Materiel Small Business Specialist, through the delegation to the resident PCTR ACO. Monthly analyses of distressed economic areas are provided to guide all procurement personnel.

Northrop's continued attention to small business and depressed area procurements is evidenced by the fact that small business concerns currently receive 61 percent of all dollars committed for materials for the T-38 and F-5 aircraft programs, and labor surplus areas currently receive 63 percent of all dollars committed on these programs.

1.5 Make or Buy Plan

1.5.1 POLICY

It is the policy of the Northrop Corporation to render "Make or Buy" decisions in accordance with PCTR. "Make or Buy" decisions will be governed by continual analysis of requirements of the Phase Change Thermal Radiator program to assure that manufacturing capability and material procurement are competitive in the areas of technical excellence, cost, and flow time without compromising design, quality, or performance.

A primary consideration in the "Make or Buy" decision is Northrop's demonstrated capability to produce the item in question. Whenever an item to be produced is compatible with Northrop's product performance history and present capability, and that capability is available to perform within time phasing requirement, the item is identified as a "Make" item. When neither of these conditions applies, the item is identified as a "Buy" item.

"Make" decisions are based on consideration of the following factors:

a) Available capacity in terms of plant and equipment, skilled manpower, machinery and special tools, and critical materials.

b) Ability to meet scheduled commitments and quality standards.

c) Favorable customer, community, and industry reaction.

d) Economically justifiable capability development costs.

e) Program constraints or contractual requirements regarding subcontracting.

"Buy" items generally consist of the following:

a) Items which are readily available from commercial sources and are identifiable to supplier nomenclature.

b) Items considered as "off-the-shelf" which are available in warehouses or jobbers stock.

c) Most requirements for common machined parts.

d) Special processes or machine operations which are low volume or nonrepetitive. This includes those operations, the lack of which will not hamper in-plant or competitive capability or would be uneconomical to "Make."

e) Parts which require manufacturing capability outside Northrop product areas, such as molded plastic or rubber, springs, clamps, couplings, etc.

1.5.2 MAKE OR BUY BOARD

Specifically, the Make or Buy Policy described above is implemented by a Make or Buy Board, chaired by the Vice President and Manager of Northrop Systems Laboratories, and consisting of the following members:

a)	V. W. Howard (Chairman)	Vice President and Manager
b)	E. W. Bentilla (Co-Chairman)	PCTR Program Manager
c)	W. Heck	Purchasing Agent
d)	William Brooner	Manufacturing Supervisor

The Make or Buy Board appoints a Source Selection Committee to handle all activities leading to the selection of an approved source. This Source Selection Committee is selected from middle management and assists the procurement group in preparing lists of potential bidders, the preparation of requests for quotation, implementing supplier surveys, evaluating submitted proposals, and making the final recommendations for supplier selection to the Make or Buy Board for approval and decision.

The complete Make or Buy Plan is described in section 4, Manufacturing Plan. The major Buy items are listed in table 1-3.

TABLE 1-3 MAJOR BUY ITEMS

Description	Recommended Source(s)
Subsystem LN_2	Hoffman Labs
Camera 16 mm	J. A. Maurer, Inc.
Tape Recorder	Kinelogic Corporation
Battery +28V 1200 watt hours	Eagle - Picker
Battery -24V 20 watt hours	Eagle - Picker

1.6 Configuration Management Plan

The scope of the Phase Change Thermal Radiator Configuration Management Plan is to:

a) Establish policy
b) Define responsibilities
c) Provide guidance in the Configuration Management function.

The objectives are to:

a) Apply a uniform methodology established to accurately identify, control, account for, and report the technical requirements which define systems, equipment, components and changes thereto.

b) Maintain the documentation prepared in compliance with standard procedures, as approved by NASA.

c) Provide technical surveillance of the Phase Change Thermal Radiator System and subsystems to assure compliance with NASA's technical requirements and direction.

In order to conform to the magnitude and cost guidelines of the PCTR Program, certain deviations are taken to the Apollo Requirement Documents (ARD) 001, 002, and 003 specified in Exhibit XVI, Configuration Management Requirements of NPC 500-1. These deviations are:

a) Data processing will be performed manually instead of electronically.

b) The frequency of data submittal, after the initial submittal, will be on a monthly basis.

c) Traceability will be maintained only to the "block box" level.

Forms such as those shown in figures 1-10 and 1-11 will be used to record the data required for submittal.

Configuration Management is based on the Northrop Systems Laboratories Practices and Procedures Manual and specifically applicable portions of the PCTR Program Directives (NSL 67-213).

1.6.1 ENGINEERING CONFIGURATION DOCUMENTATION

Release of Engineering documents (figure 1-12) is administered by Configuration Identification and Accounting. This unit also records the level of every assembly and of every deliverable item made for and accepted by NASA.

END ITEM TITLE	Size	Part No.	Rev.	Code	E.I. Serial No.	NHA Effectivity			Total Qty. Req'd
						NHA No.	Serial No.	Qty/ NHA	

REMARKS: (EO, ECP, FACI, etc., Action)

Life Cycle Critical	Yes		No		Qual. Testing Req'd.	Yes		No	

Item No.	Detail Part	Size	Part. No.	Rev.	Code	Material	Specification	Qty.	AMR. No.	

End Item Title	Part No.	Page___of___

FIGURE 1-10 ENGINEERING DRAWING AND EO MASTER FILE

Engineering Change Proposals (ECP's) will be prepared in accordance with Northrop Systems Laboratories PCTR Program Directive P.D. 31 (NSL 67-213), using Northrop Systems Laboratories forms.

All drawing data elements of details, assemblies and Contract End Items (CEI) of hardware are recorded by Engineering Release Records. For the End Items, these records show number, all serial numbers released, specification identification, and top drawing number.

PCTR DOCUMENTATION CONTROL MASTER FILE

Document No			Rev.	Title		
Documentation Category			Type	I.D. Code	Supersedes Document No.	Rev
Effectivity	Scheduled Release Date	Issue Date	Fwd'd Date	Approval Date	Not Approved	Reason
Remarks						

FIGURE 1-11 PCTR DOCUMENTATION CONTROL MASTER FILE

For drawings, the data elements include the drawing number, title, code identification, number of sheets, release date, change letter and date thereof, any ancillary document numbers, specification documents, and specification or source control drawing numbers.

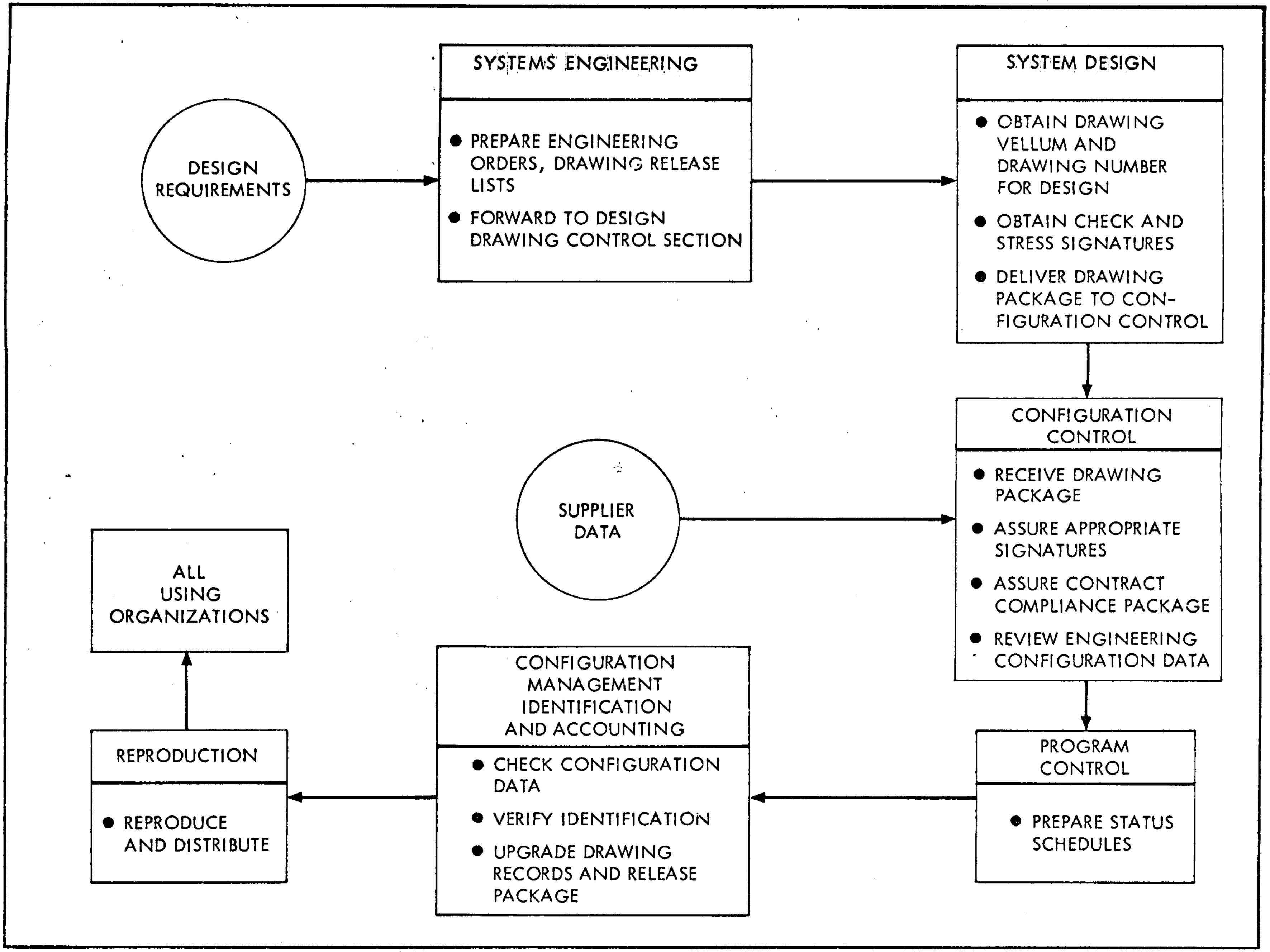


FIGURE 1-12 ENGINEERING RELEASE SYSTEM

Records for part numbers include controlling drawing numbers, part numbers released, the change letter which created the part number, and the change identification number which created the part number (EO No.).

The release records system is capable of determining at any time the Class I and Class II change identification numbers which have been partially or completely released for any part number and corresponding end item number and serial number.

The top drawing is identified to the End Item by including on the drawing number, End Item nomenclature, part number, and manufacturer's code identification number.

The released engineering records are structured to be capable of:

a) Reconciling engineering work authorizations to contract requirements and work breakdown structure.

b) Verifying that released engineering and purchase order data for selected items are in accordance with contract requirements.

c) Assuring that equipment is manufactured and installed as defined by released engineering data.

d) Documenting engineering changes required for formal acceptance.

Inspection records, together with released engineering records of the "as-built" configuration, are used for verification of a closed-loop relationship between specifications, drawings, and hardware.

The formats to be used for the accountability, traceability, and documentation records are shown as figures 1-10 and 1-11.

1.6.2 PRODUCT IDENTIFICATION

1.6.2.1 Part Numbers

Part numbers will be assigned in accordance with the requirements of MIL-STD-100 and Northrop Systems Laboratories Program Directive P.D. 08.

1.6.2.2. Serial Numbers

All engineering critical and logistics critical components of a contract end item will be serialized by drawing and part number. The permanent drawing number portion of the drawing and part number will be the base for serializing a critical component, assembly, or part. Serial numbers will begin with number 1 (one) and will be permanently assigned in numerical sequence within the permanent drawing number portion of the drawing and part number. A new serial number sequence will not be assigned when the part number is changed to identify a noninterchangeable design. The serial number of a reworked or retrofit item will not be changed even though the item has been identified by a new part number.

1.6.2.2.1 PRODUCT MARKING -- Product marking will be in accordance with MIL-STD-130.

1.6.2.2.2 MATERIAL TRACEABILITY -- A traceability master file will be maintained which records the installation, removal, and reinstallation of equipment on the PCTR. The master file maintains traceability of all serialized units of equipment.

1.6.2.3. Drawings

Drawings to be furnished under the terms of the contract will be Category E, Form 2 for deliverable hardware and Category E, Form 3 for nondeliverable hardware and will be prepared in accordance with the requirements of MIL-STD-1000.

1.6.2.4 Procedures

1.6.3.4.1 IDENTIFICATION -- The engineering drawings will be identified from a block of numbers assigned by Northrop Systems Laboratories and by the Northrop Systems Laboratories Code Identification Number. Once assigned, drawing numbers will not be changed in any respect or assigned to another drawing. The family number for an interchangeable and noninterchangeable item in a family will be the same.

1.6.2.4.2 VENDOR PARTS -- Vendor parts are identified in the list of material on engineering drawings by vendor part numbers which provide the vendor's name, address, and manufacturing code number. Items controlled by a specification or Source Control Drawing are referenced on the applicable drawings by the Specification or Source Control Drawing Number.

1.6.2.4.3 REIDENTIFICATION -- Production drawing reidentification will be in accordance with Northrop Systems Laboratories Program Directive P.D. 08.

1.6.2.4.4 COMPANY STANDARD PARTS AND DRAWINGS -- Company Standard Parts and Drawings will be in accordance with Northrop Systems Laboratories Program Directive P.D. 08.

1.6.2.4.5 ELECTRICAL AND ELECTRONIC SYMBOLS -- Electrical and Electronic symbols will be selected in accordance with the requirements of Northrop Systems Laboratories Program Directive P.D. 08.

1.6.2.4.6 USE AND REFERENCING OF SPECIFICATIONS -- Use and referencing of specifications will be in accordance with Northrop Systems Laboratories Program Directive P.D. 08.

1.6.2.5 Specifications

Preparation of Specifications will be in accordance with Exhibit II of NPC 500-1, as amended by Supplement I thereto. Once the baseline is established, the specifications are controlled and documented in accordance with the method defined in paragraph 1.6.1. Changes are documented in accordance with Northrop Systems Laboratories Program Directive P.D. 02.

1.7 Configuration Control

A functional Configuration Review Board will be established for the PCTR Program. This board will function under the direction and chairmanship of the Program Manager or his alternate. The board will consist of representatives of each organization, each having full authority to commit his respective organization.

The Configuration Review Board will maintain surveillance over all proposed changes. The board will evaluate the total impact of proposed changes such as performance, cost, schedules, and effectivities. The Configuration Review Board will be implemented in accordance with Northrop Systems Laboratories Program Directive P.D. 09.

1.7.1 ENGINEERING CHANGE CLASSIFICATIONS

Engineering Change Classifications will be in accordance with ANA Bulletin 445.

1.7.2 SUPPLIER CONTROL

Supplier Control will be in accordance with Northrop Systems Laboratories Program Directives P.D. 07, P.D. 11 and P.D. 27.

1.8 PERT and Integrated Cost Plan

The PERT and Integrated Cost Plan is presented in two parts. Part I discusses PERT time (Program Evaluation and Review Technique) and its associated schedules; and Part II defines Northrop's Integrated Cost Control System. No attempt has been made to describe the mechanics of the PERT system, since this is already adequately covered in detail in the NASA PERT and Compantion Cost Handbook and the other related PERT B and PERT C Computer System Manuals. This plan does, however, follow the procedures included in the manuals and describes how Northrop uses the plan as a management tool in the execution of the PCTR Phase IV Program.

Since Northrop currently uses an Integrated Cost Control System (ICCSO) which essentially furnishes the same cost controls as does the Companion Cost, it has proven more expedient and economical to remain with a system fully compatible with Northrop's accounting system. Additionally, Northrop's Integrated Cost Control System blends into the Management Control Plans more readily than does the Companion Cost System. This ICCS and how it will be implemented during the PCTR Phase IV Program is described in Part II of this plan.

As explained more fully in subsection 1.8.3, Summary Network and PERT biweekly reports will be furnished to NASA at the summary level. Internal monitoring and control will be accomplished at the more detailed fragnet levels. If NASA desires fragnets and reports at these lower levels, copies may be provided either for only these areas which have program problems, or for all areas.

Part I, subsection 1.8.1, defines the correlation of the Management Control Plans, PERT, schedules, and the Work Breakdown Structure, and includes a Correlation Flow Chart. Subsection 1.8.1.2 further defines the Work Breakdown Structure and provides a Work Breakdown Structure tree. Subsection 1.8.1.3 explains how PERT is used. Subsection 1.8.1.4 provides a Master Milestone Schedule and Detailed Phasing Schedules, and includes a resume of the program requirements and criticalities. This subsection also discusses Recovery Schedules and Line of Balance (LOB).

The PCTR Phase IV Program is based upon certain assumptions and ground rules which are covered in this Program Plan. This PERT and Integrated Cost Plan will be updated during the early period of the Phase IV Program to reflect all negotiated statements of work schedules and contractual conditions. The schedules of subsection 1.8.1.4 and the Work Breakdown Structure of subsection 1.8.1.1 will be revised at that time and submitted with the first PERT network submittal.

1.8.1 PART I - PERT TIME AND ASSOCIATED SCHEDULES

1.8.1.1 MCP/PERT/Schedule Correlation

For the PCTR Phase IV Program, Northrop will correlate the Management Control Plans, PERT, schedules, Work Breakdown Structure, and Sales Order Cost Structure into an integrated system which assures both overall program compatibility and maximum control. Figure 1-13, MCP/PERT/Schedule Correlation Chart, gives an example of these interrelationships for a previous program. As shown, the tasks and subtasks in the Management Control Plan are the same tasks or subtasks (or activities) as those on the PERT network. Identification of each task is accomplished by the use of the last four digits of the eight-digit sales order, and by dash numbers. The first four digits would serve to identify the program within Northrop wherein the first digit identifies Northrop Systems Laboratories, the second digit the contract type, and the third and fourth digits the PCTR Program. The second group of four digits specifically identifies the hardware, the responsible organizational group, and the task (or functional) area affected. The dash numbers specifically identify each subtask or activity. In the example shown, the last four digits, 2121, identify the hardware for the Qualification Model, the ancillary equipment within the QM, and the Systems Engineering Task Area. The dash number, 027, specifically identifies the activity to "Define Test Requirements." This activity is itemized on the MCP where relevant data is given, such as the Product Task Area (Test Requirements Specification); Subsequent Use of the Task; Previous Constraining Task (2121-025-Predecessor Activity; the man-months estimated to perform the task (one man-month); and the milestone schedule.

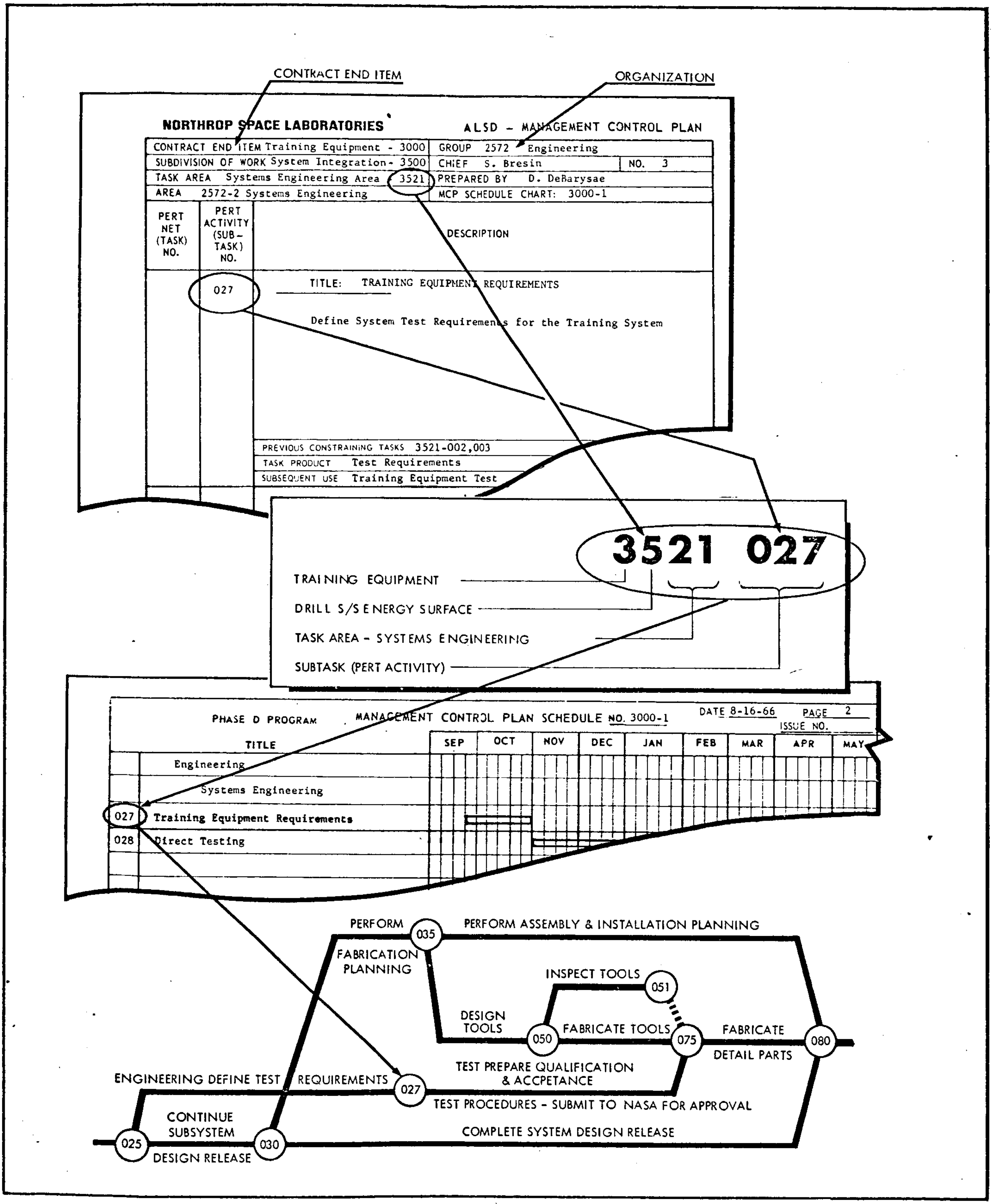


FIGURE 1-13 MCP/PERT/SCHEDULE CORRELATION CHART

1.8.1.2 Work Breakdown Structure

Figure 1-14 is a "tree" of the Work Breakdown Structure segregated to the third level. As explained in the previous section, the four-digit identification numbers shown in each block of the WBS are the last four digits of the eight-digit sales order. For a complete listing of the sales-order pattern see Part II of this Plan, subsection 1.8.2. Also shown in Part II is the Work Breakdown Structure in cost matrix format.

The PERT Networks are keyed to the same four-digit numbers listed in each WBS block. Both the networks and the Work Breakdown Structure are primarily oriented to hardware, but all other significant program functions, such as Program Control, Configuration Management, and Supervision are also covered. The activities (subtasks) in the MCP's and PERT networks are further identified by dash numbers and are a fourth level of indenture, not shown on the Work Breakdown Structure. Total program direct effort for the PCTR Program is encompassed within the Work Breakdown Structure.

1.8.1.3 Program Evaluation and Review Technique

1.8.1.3.1 PHASE IV PERT OPERATIONS -- Upon contract award, the Statement of Work will be reviewed to assure that the existing logic and program requirements are valid. Requirements of the SOW will be incorporated in both the fragnets and schedules. When they are then compatible to the program requirements, and to the Management Control Plans which will also be revised to conform to SOW requirements, Phase IV PERT will be implemented. Once the networks have been revised, the following operational cycle will occur:

a) Biweekly, line supervisors or delegated representatives will furnish status and forecast data oriented to specific fragnets. Status will be as of a predetermined cutoff date, and forecast data will be on a projection of eight weeks. New time estimates will be entered on a copy of the previous network publication. Activities will be added or deleted, and replanning of series or concurrent paths will be completed.

b) Once all data is appropriately incorporated in the fragnet level charts, information will be extracted to update the "Integrated Summary Network."

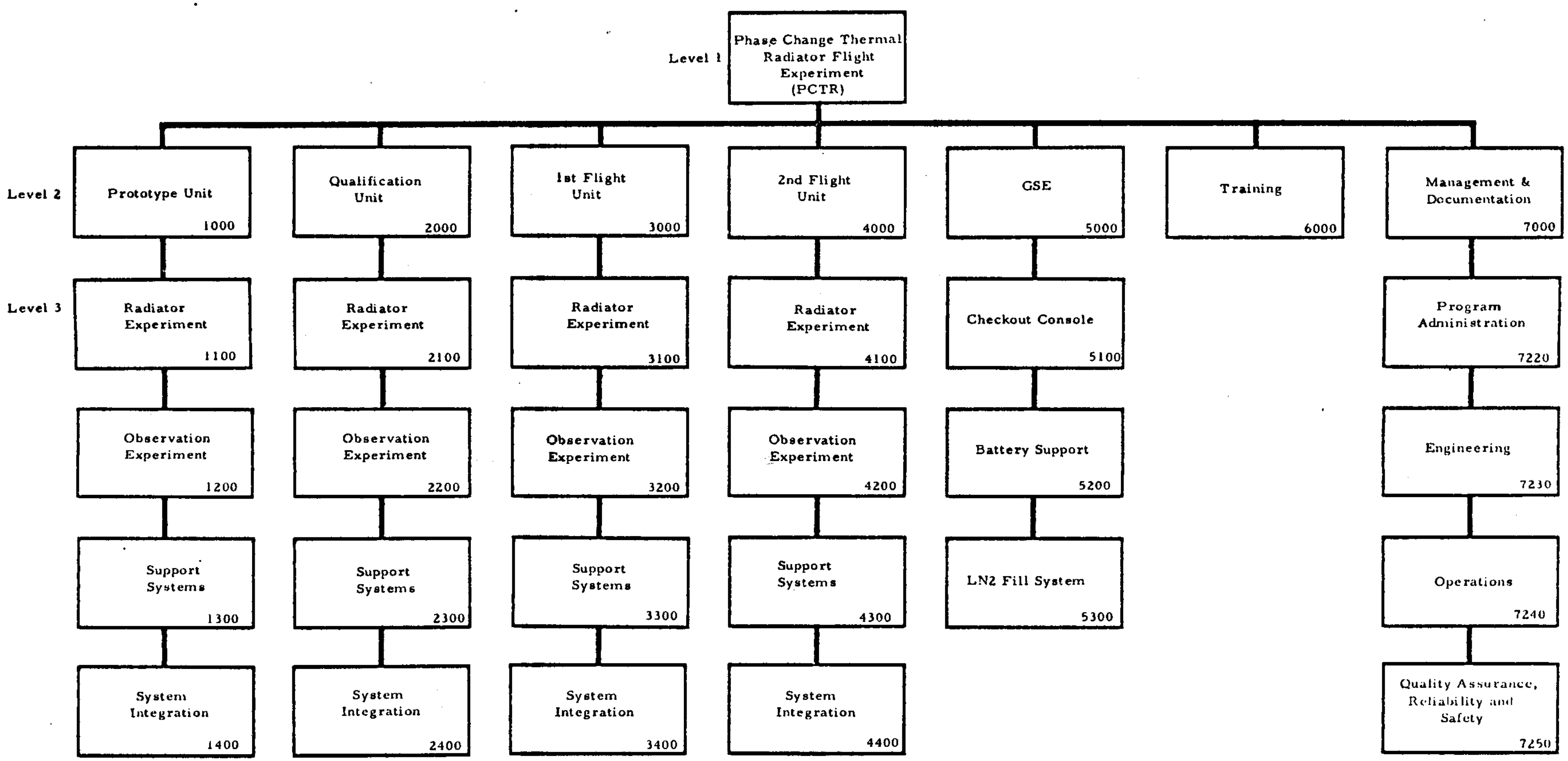


FIGURE 1-14 WORK BREAKDOWN STRUCTURE

c) The magnetic boards will be updated in accordance with the Integrated Summary Network and photographed. Photo copies will then be processed and forwarded to NASA.

The follow-on cycle of analysis, problem resolution, generation of corrective action, and submittal of the network and Situation Summary Reports will be reduced to a respective series of tasks for each update cycle. When necessary, and time does not permit, Northrop will furnish advanced data by telephone or TWX to NASA/MSFC to enable subsequent response to another NASA echelon or agency, if required.

1.8.1.3.2 NETWORK DEVELOPMENT -- Initial development of network flow charts, which later are upgraded to PERT Time Oriented Fragnets, are accomplished at Northrop on a progressive step-by-step basis. Each step is accomplished successively to assure correlation of data without undue delay. The Northrop Program Control PERT analysis will develop the networks as follows.

a) Establish the Program Master Milestone predicated on contractual mandatory requirements and related schedule exhibits in the contract Statement of Work. The critical dates affixed to the milestones then serve as precise parameters to which all organizational areas must adhere.

b) Obtain the current Management Control Plans to identify subtasks (activities) for each organizational area. These activities are completed in detail and are organized to encompass planning logic and time estimates, as well as interrelationships of effort within Northrop and with outside support.

c) Transfer MCP data to network planning format. Plot activities in series by program element (i.e.,GSE, Mockup, etc.), identify constraints, assign organization responsibility, and denote realistic time estimates.

d) Determine the "Critical Path," and its flow and relationship to Program Master Milestones by Analytical Technique. Alert management and/or the organizational counterpart of problem areas that jeopardize prime objectives. Pay heed to outside references and their impact on timely accomplishment of subsequent activities.

e) Generate corrective action to rectify incompatibilities by negotiation. Resolve schedule differences by resource exchanges, sequence replanning, premium time effort, manloading assignment, multishift operation, and/or adjustment to priority control.

f) Develop (when necessary) additional temporary subnetworks to simulate and encompass problem areas and maintain some for the duration to ensure effective management and control. The level of details for these subnetworks is dictated by the technical nature and magnitude of activity. Monitoring must be accomplished at a level that satisfies timely accomplishment and problem resolution.

Steps (a) through (b) denote a progressive procedure and evolution of network development from chart form to computerized print-out. Because the Management Control Plans provide "depth control" at the subtask level (activities at level 4 and below), Northrop does not plan to computerize effort at the fragnet level of detail for Phase IV. However, the Integrated Summary Network will be placed on magnetic boards and photo copies of this network will be furnished to NASA biweekly. Along with these network photos will be the Situation Summary Report whenever any problems require it.

1.8.1.3.3 PERT FRAGNETS -- Using the Work Breakdown Structure for area designation, and the MCP's for activities identification, a series of eleven PERT fragnets will be developed during Phase IV. As previously mentioned, these fragnets are primarily oriented to Contract End Item (CEI) hardware, but flows of activities also encompass all other program areas since each subtask in the MCP's are also activities in the PERT Networks, and all tasks and subtasks for the Program are encompassed within the MCP's.

1.8.1.3.4 PERT INTEGRATED SUMMARY NETWORK -- A Summary Network will be furnished to NASA biweekly during Phase IV of the PCTR. It summarizes the significant milestones from the beginning of contract award through to completion.

During Phase IV after PERT has been implemented, problems will be identified systematically. Whenever analysis shows that these problems are serious or critical, a "Situation Summary Report" will be prepared and submitted to NASA with the network photos -- one page for each problem. Figure 1-15 is a copy of the Situation Summary Report form, with an example of a typical problem which

NORTHROP SYSTEMS LABORATORIES

SHEET ___ OF ___

SITUATION SUMMARY REPORT

REF: NETWORK: ____________

STATUS OF: ____________

SUBJECT ____

1. PROBLEM:

2. SCHEDULE:

3. IMPACT:

4. SOLUTION:

5. RECOVERY:

PREPARED BY: ____________________

DATE: ________________

TRANSMITTED TO NASA ON: ____________

SUBMITTED BY: ____________

DATE: ____________

CONTRACT NO. ____________

FOR NASA USE

ISSUE ________________ CLOSE OUT AND FILE BY: ________________ DATE: ________

NSL FORM NO. 105

FIGURE 1-15 SITUATION SUMMARY REPORT

could occur during actual operations. The Program Control PERT analyst first detects the problem. When he has determined that it warrants attention, he initiates the Report, filling out the first three items, i.e., (1) Problem, (2) Schedule, (3) Impact. He then forwards it to the Chief responsible for the group wherein the problem lies, who takes corrective action and fills in the Solution - item 4. The form is then returned to Program Control and, (4) Recovery, is entered. After assuring that all other pertinent data is entered, it is submitted to NASA. All reports are reviewed during the Program Managers Program Conference Review.

Some reports may require NASA approval. A "For NASA Use" block has been provided for this purpose.

1.8.1.4 Schedules

1.8.1.4.1 MASTER MILESTONE SCHEDULE -- The Master Milestone Schedule (Figure 1-16) establishes the overall parameters of the Phase IV PCTR Program. A 12-month program is scheduled, beginning with a contract go-ahead of February 1968, and concluding in January 1969. Using the start and delivery dates provided in the NASA Phase IV Statement of Work and subsequent delivery dates furnished by NASA, Northrop established intermediary milestones.

Figure 1-16 lists delivery dates, as well as the more significant intermediary end milestones. It is assumed that the preliminary design review will be accomplished during the negotiations at MSFC prior to contract award. Thus, the design requirements baseline will be established and approved by NASA. All CEI specifications will be updated and approved so that detailed design and drawing releases can be started immediately upon contract award. The Critical Design Review is scheduled at the end of the 4th month after contract award, or about 1 June 1968. By this time, all formal drawings will be complete. Upon approval of the drawings by NASA, formal release will begin. Because of long-lead procurement items in many areas, placing of purchase orders will be accomplished prior to CDR. However, no manufacturing of flight hardware will take place until after the Critical Design Review. Formal drawing release will be completed by May 1968 after Critical Design Review.

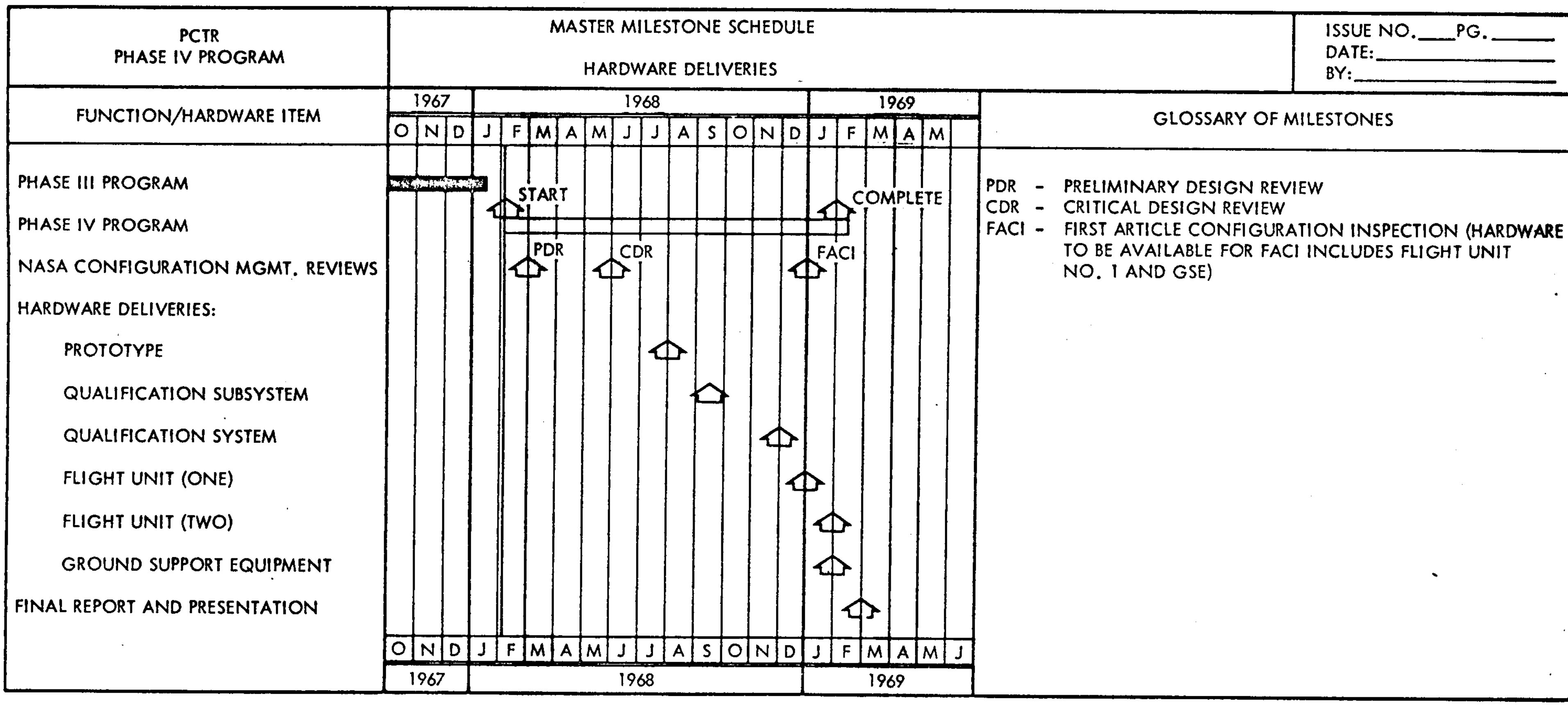


FIGURE 1-16 MASTER MILESTONE SCHEDULE

First Article Configuration Inspection (FACI) is scheduled for January 1969. This is the time when the first flight article will be complete through checkout and ready for NASA Final Acceptance. FACI will be conducted on the first flight article.

1.8.1.4.2 DETAILED PHASING SCHEDULE

The Phase IV Detailed Phasing Schedule consists of 2 pages, segregated by organizational programs. Figure 1-17 includes Management and Engineering Programs. Figure 1-18 includes Procurement, Reliability, and Quality Control Programs.

The purpose of the Detailed Phasing Schedule is to be sufficiently complete to stand on its own and to give the reader a comprehensive picture of Northrop's Phase IV development and demonstration program. It is intentionally detailed to show depth and thoroughness so as to assure the reader that the Phase IV schedule requirements are indeed feasible. Milestones are coded with adequate explanations to enable the reader to understand the relationships and interfaces. Each milestone is phased with all other milestones within its own program, as well as being phased with all other milestones in the total program.

By referring to the schedule, it will be noted that the left and right sides are marked off in columns. The left side is organizationally and hardware oriented, while down the right side will be found a Glossary of Milestones. The milestones and bars, oriented to time, are plotted horizontally across the chart. Usually, when only completion dates for specific events are required, milestone symbols only are used. When it is more feasible to show start and completion, bars are also used. Bars are preferred wherever possible so that overlap within scheduled events can be shown; also, they can be used for reference when determining general manload requirements. In the majority of cases, combinations of both milestones and bars are used. NASA standard symbology as called out in the NASA PERT and Companion Cost Handbook, dated October 1962, is used. To make NASA's Interface/Approval milestones stand out above Northrop's internal milestones, a slightly different symbol is used. The standard NASA arrowhead is used for the NASA Interface/Approval milestones; whereas a triangle is used for Northrop.

PCTR

PHASE IV PROGRAM

MANAGEMENT AND ENGINEERING PROGRAMS

PHASE III PROGRAM

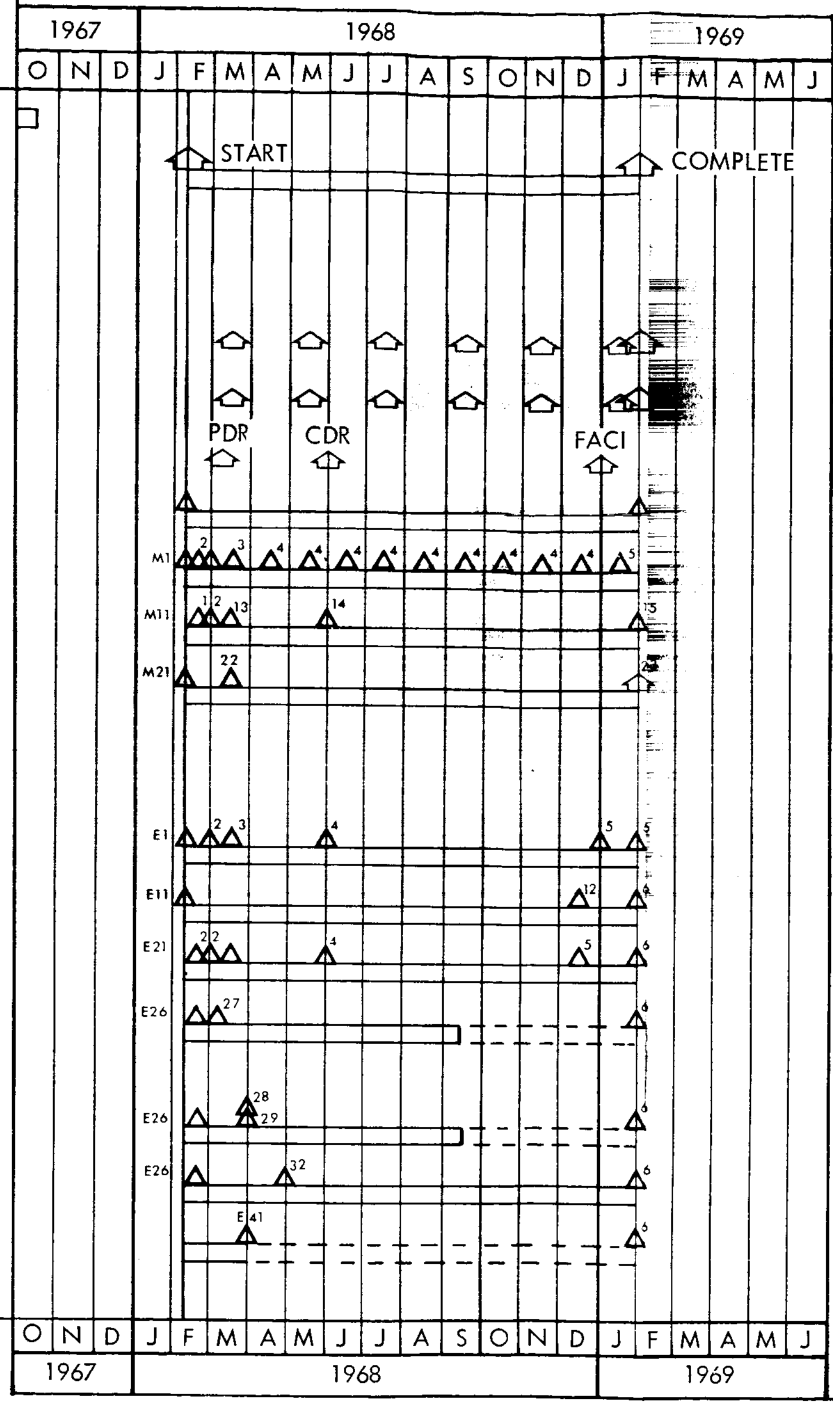
PHASE IV PROGRAM

MANAGEMENT PROGRAM

- MANAGEMENT REVIEWS -- NASA/NORTHROP
- **INTERFACE MTGS -- CONTRACTORS & EXPMTR**
- NASA CONFIG. MANAGEMENT REVIEWS
- NASA LIAISON
- PROGRAM CONTROL
- CONFIGURATION MANAGEMENT
- FACILITIES

ENGINEERING PROGRAM

- PLANS AND PROCEDURES
- SYSTEM ENGINEERING
- DESIGN ENGINEERING
  - PROTOTYPE
  - QUALIFICATION UNITS
- FLIGHT UNITS
- GROUND SUPPORT EQUIPMENT



GLOSSARY OF MILESTONES

MANAGEMENT CODE

PDR PRELIMINARY DESIGN REVIEW. NASA APPROVES DESIGN CONCEPT AND AUTHORIZES CONTINUATION OF DETAIL DESIGN. DESIGN CONFIGURATION BASELINE CONFIRMED BY NASA.

CDR CRITICAL DESIGN REVIEW. NINETY PERCENT OF DESIGN IS COMPLETE. NASA REVIEWS FINAL DESIGN AND APPROVES.

FACI FIRST ARTICLE CONFIGURATION INSPECTION. NASA INSPECTS FIRST FLIGHT UNIT FOR CONFORMITY AND COMPATIBILITY WITH DRAWINGS AND SPECIFICATIONS. MEI SPECIFICATIONS COMPLETE AND ALL FORMAL DOCUMENTATION REQUIRED FOR FACI AVAILABLE. PRODUCT CONFIGURATION BASELINE WILL BE CONFIRMED BY NASA AT COMPLETION OF FACI.

MANAGEMENT REVIEWS - CONDUCTED MONTHLY, TWO WEEKS AFTER THE CLOSE OF THE MONTHLY PERIOD (APPROXIMATELY ONE WEEK FOR FIRST REVIEW). THIS WILL ALLOW TIME FOR COST ACCUMULATION AND COMPILATION OF PRESENTATION DATA.

INTERFACE MTGS - HELD EVERY FIVE WEEKS AT MSFC. (PREDICATED UPON NORTHROP FISCAL MONTH CALENDAR AS TO NUMBER OF WEEKS PER MONTH.)

M1 CONDUCT WEEKLY MANAGEMENT REVIEWS AND EXERCISE PROGRAM CONTROL OF PCTR.

M2 UPDATE PROGRAM PLANS TO CONFORM TO NEW CONTRACT STATEMENT OF WORK.

M4 PHASE IV PERT NETWORKS REVISED TO CONFORM TO NEW SOW. REVISE MONTHLY, INCLUDING PERT MONTHLY REPORT TO NASA.

M5 COMPLETE PROGRAM CONTROL PORTION OF FINAL REPORT.

M11 DRAWING RELEASE SYSTEM IMPLEMENTED. BEGIN RELEASE OF DRAWINGS FOR DEVELOPMENT HARDWARE. MAINTAIN DRAWING RELEASE CONTROL.

M12 CONFIGURATION REVIEW BOARD IMPLEMENTED.

M13 CONDUCT PDR.

M14 CONDUCT CDR.

M15 CONDUCT FACI.

M16 COMPLETE CONFIGURATION MANAGEMENT PORTION OF FINAL REPORT.

M21 NORTHROP FACILITIES AVAILABLE FOR IMPLEMENTATION OF PHASE IV.

M22 COORDINATE NORTHROP SITE REQUIREMENTS TO SUPPORT PCTR.

M23 DEACTIVATE NORTHROP SITE SUPPORT ACTIVITIES.

ENGINEERING CODE

E1 CONTRACT AWARD. BEGIN ENGINEERING EFFORT IN PHASE IV PROGRAM.

E2 UPDATED ENGINEERING PLAN TO CONFORM TO NEW CONTRACT STATEMENT OF WORK. MAINTAIN THROUGHOUT PHASE IV PROGRAM.

E3 COMPLETE ALL ENGINEERING DOCUMENTATION FOR PRELIMINARY DESIGN REVIEW AND HOLD PDR.

E4 COMPLETE ALL ENGINEERING DOCUMENTATION FOR CRITICAL DESIGN REVIEW AND HOLD CDR.

E5 COMPLETE ALL ENGINEERING DOCUMENTATION FOR FACI, AND HOLD FACI. INCLUDES ALL FORMAL DRAWINGS AND PART II CEI SPECS.

E6 COMPILE ALL ENGINEERING DATA DEVELOPED DURING PHASE IV AND SUMMARIZE INTO FINAL REPORT.

E11 REVIEW TRADE STUDIES IN LIGHT OF NEW CONTRACT STATEMENT OF WORK AND CONTINUE EFFORT AS REQUIRED.

E12 PRODUCT CONFIGURATION BASELINE ESTABLISHED IN CONJUNCTION WITH NASA AND FACI.

E21 DESIGN ENGINEERING ADVANCE RELEASE SPECS AND DATA SUFFICIENTLY TO ALLOW PROCUREMENT TO PREPARE PURCHASE ORDERS FOR LONG LEAD CRITICAL ITEMS; AND TO ALLOW MANUFACTURING TO BEGIN DETAIL PLANNING AND PRELIMINARY TOOL DESIGN. (PROCUREMENT AND MANUFACTURING WILL PROVIDE DESIGN ENGINEERING WITH PRIORITY LISTS OF THEIR MOST CRITICAL ITEMS.)

E22 COMPLETE RELEASE OF ALL SPECIFICATIONS FOR PROCUREMENT PURPOSES.

E23 BASIC DESIGN CONFIGURATION BASELINE ESTABLISHED FOR PDR.

E24 NINETY PERCENT OF DETAIL DESIGN DRAWINGS COMPLETE AND READY FOR CDR. INCLUDES INITIAL PART II CEI SPECS.

E25 ALL FORMAL DESIGN DRAWINGS COMPLETE AND AVAILABLE FOR FACI. INCLUDES COMPLETE PART II CEI SPECS.

E26 BEGIN RELEASE OF DETAIL DRAWINGS FOR DEVELOPMENT HARDWARE.

E27 COMPLETE RELEASE OF DETAIL DRAWINGS FOR THE PROTOTYPE.

E28 COMPLETE RELEASE OF DETAIL DRAWINGS FOR QUALIFICATION SUBSYSTEM.

E29 COMPLETE RELEASE OF DETAIL DRAWINGS FOR QUALIFICATION SYSTEM.

E32 COMPLETE RELEASE OF DETAIL DRAWINGS FOR FLIGHT UNITS.

E41 RELEASE SPECIFICATION FOR GSE PROCUREMENT.

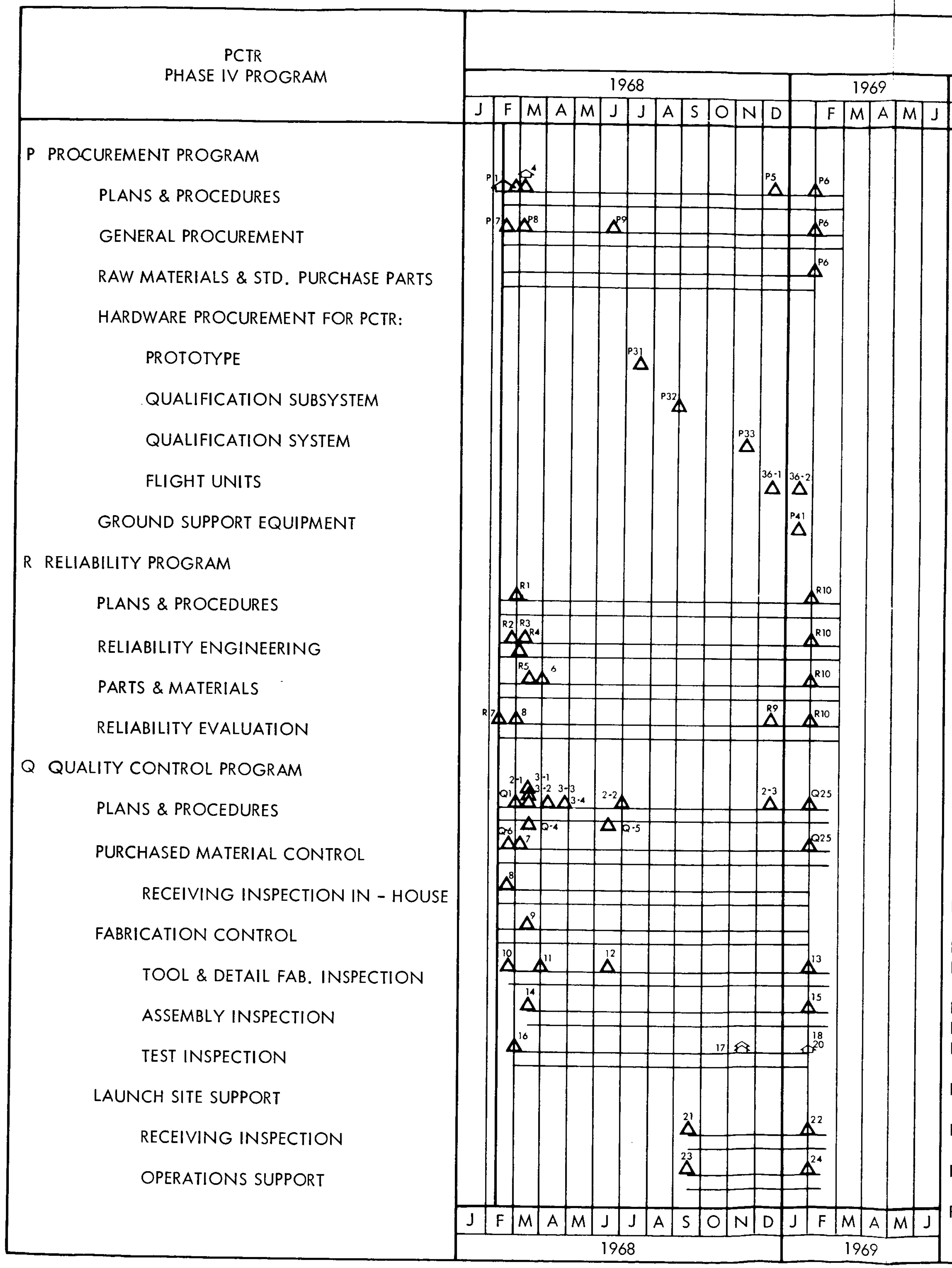
LEGEND

NASA STANDARD SCHEDULE SYMBOLOGY

- NASA APPROVAL/ACCEPTANCE MILESTONE
- NORTHROP MILESTONE
- COMPLETED MILESTONE
- MILESTONE NUMBER REF.
- SCHEDULED ACTIVITY
- COMPLETED ACTIVITY

NOTE: SINCE PHASE IV HAS NOT BEGUN, ALL SYMBOLS AND BARS ARE SHOWN OPEN. (EXCEPT PHASE III BAR, WHICH IS SHOWN COMPLETED). WHEN PHASE IV BEGINS, THE ABOVE NASA TECHNIQUE WILL BE USED TO MONITOR SCHEDULE COMPLIANCE AND PROGRESS.

FIGURE 1-17 DETAILED PHASING SCHEDULE/MANAGEMENT AND ENGINEERING PROGRAMS



GLOSSARY OF MILESTONES

PROCUREMENT CODE

P1 CONTRACT AWARD. BEGIN PROCUREMENT EFFORT IN PHASE IV.
P2 REVISE MAKE OR BUY PLAN AND SUBMIT TO NASA FOR APPROVAL
P3 UPDATE PROCUREMENT FUNCTIONAL PLAN TO CONFORM TO NEW SOW.
P4 NASA APPROVE MAKE OR BUY PLAN.
P5 PROVIDE SUPPORT AS REQUIRED FOR FACI.
P6 COMPILE ALL DATA DEVELOPED THROUGHOUT PHASE IV PROGRAM AND SUMMARIZE INTO FINAL REPORT.
P7 BEGIN RELEASE OF ADVANCED PURCHASE ORDERS FOR CRITICAL LONG LEAD ITEMS. (DONE ON MANAGEMENT RISK UNTIL NASA APPROVES MAKE OR BUY PLAN.)
P8 CONDUCT SUPPLIER LIAISON AS REQUIRED, INCLUDING PERIODICALLY ESTABLISHED MEETINGS THROUGHOUT PROCUREMENT CYCLE.
P9 COMPLETE RELEASE OF PURCHASE ORDERS FOR FLIGHT HARDWARE.
P10 BASIC PROCUREMENT EFFORT COMPLETE.
P21 PROCUREMENT RAW MATERIALS AND STANDARD PURCHASE PARTS (NUTS, BOLTS, SCREW, RAW STOCK, ELECTRONIC PARTS, ETC.) AS REQUIRED TO SUPPORT THE PHASE IV PROGRAM.
P31 RECEIVE LAST OF PROCURED PARTS FOR STRUCTURAL PROTOTYPE
P32 RECEIVE LAST OF PROCURED PARTS FOR THE QUALIFICATION SUBSYSTEM.
P33 RECEIVE LAST OF PROCURED PARTS FOR THE QUALIFICATION SYSTEM.
P36 RECEIVE LAST OF PROCURED PARTS FOR FLIGHT UNIT NO. 1 AND FLIGHT UNIT NO. 2. (P36 - 1 = FLIGHT UNIT NO. 1, P36 - 2 = FLIGHT UNIT NO. 2.)
P41 RECEIVE LAST GSE PARTS.

RELIABILITY CODE

R1 UPDATE RELIABILITY PLAN TO CONFORM TO NEW SOW. MAINTAIN THROUGHOUT PHASE D PROGRAM.
R2 COMPLETE FINAL RELIABILITY ALLOCATION.
R3 UPDATE RELIABILITY PREDICTION AND MAINTAIN THROUGHOUT PROGRAM.
R4 INITIATE FAILURE MODE EFFECT ANALYSIS AND MAINTAIN.
R5 RELEASE PARTS LISTS.
R6 CONDUCT PART FAILURE ANALYSIS AS REQUIRED THROUGHOUT PROGRAM.
R7 INITIATE QUALIFICATIONS STATUS LIST AND MAINTAIN THROUGHOUT PROGRAM.
R8 UPDATE RELIABILITY EVALUATION PLAN TO CONFORM TO NEW CONTRACT SOW.
R9 RELEASE RELIABILITY ASSESSMENT STATUS REPORT FOR FLIGHT UNITS.
R10 COMPILE ALL DATA DEVELOPED DURING PHASE D PROGRAM AND SUMMARIZE INTO FINAL REPORT.

QUALITY CONTROL CODE

Q1 UPDATE QUALITY CONTROL PLAN TO CONFORM TO NEW SOW AND MAINTAIN THROUGHOUT PROGRAM.
Q2 PARTICIPATE IN DRAWINGS AND SPECIFICATIONS REVIEW AT PDR, CDR, AND FACI (Q2 - 1 = PDR; Q2 -2 = CDR; Q2 - 3 = FACI).
Q3 REVIEW ACCEPTANCE TEST PROCEDURES PRIOR TO SUBMITTAL TO NASA.
- Q3 - 1 PROTOTYPE
- Q3 - 2 QUALIFICATION SUBSYSTEM
- Q3 - 3 QUALIFICATION SYSTEM
- Q3 - 4 FLIGHT UNITS

Q4 IMPLEMENT PROCESS CONTROLS AND MAINTAIN THROUGHOUT PROGRAM.
Q5 PARTICIPATE IN PREPARATION OF MANUFACTURING PLANNING -- COMPLETE.
Q6 BEGIN SUPPLIER SURVERYS.
Q7 BEGIN SOURCE SELECTION.
Q9 IMPLEMENT FAILURE REPORTING SYSTEM AND MAINTAIN THROUGHOUT PROGRAM.
Q10 BEGIN INSPECTION OF DETAIL FABRICATION .
Q11 BEGIN INSPECTION OF TOOL FABRICATION.
Q12 COMPLETE INSPECTION OF ASSEMBLY AND INSTALLATION TOOLS.
Q13 COMPLETE INSPECTION OF DETAIL FABRICATION FOR ALL DELIVERABLE HARDWARE.
Q14 BEGIN FINAL ASSEMBLY INSPECTION.
Q15 COMPLETE FINAL ASSEMBLY INSPECTION OF ALL DELIVERABLE HARDWARE.
Q16 BEGIN TEST INSPECTIONS ON SUBASSEMBLY AND SUBSYSTEMS LEVEL TESTS.
Q17 COMPLETE TEST INSPECTIONS ON SUBASSEMBLY AND SUBSYSTEMS LEVEL TESTS.

Q18 COMPLETE COMPANY FINAL INSPECTIONS AND NASA FINAL ACCEPTANCES ON ALL DELIVERABLE HARDWARE.
Q19 PARTICIPATE IN FACI.
Q20 COMPLETE COMPANY FINAL INSPECTION AND NASA FINAL ACCEPTANCES ON ALL DELIVERABLE GSE.
Q21 BEGIN RECEIVING INSPECTIONS ON HARDWARE DELIVERED TO KSC.
Q22 COMPLETE RECEIVING INSPECTIONS AT KSC.
Q23 PROVIDE Q.C. SUPPORT AT KSC AS REQUIRED.
Q24 ASSIST AS REQUIRED IN SITE DEACTIVATION SUPPORT.
Q25 COMPILE ALL DATA DEVELOPED DURING PHASE IV PROGRAM AND SUMMARIZE INTO FINAL REPORT.

FIGURE 1-18 DETAILED PHASING SCHEDULE PROCUREMENT, RELIABILITY AND QUALITY CONTROL PROGRAMS

Because the Detailed Phasing Schedule is oriented both to organizations and hardware, the reader can get an overall perspective of the hardware requirements, as well as organizational responsibilities. The Detailed Phasing Schedule is correlated to the Management Control Plan and PERT Network. By studying each schedule and reading the Glossary of Milestones, with explanations and notes, the reader can obtain a detailed explanation of how Northrop will design, procure, manufacture, and checkout each PCTR system and its associated equipment, mockups, and training equipment.

1.8.1.4.3 RECOVERY SCHEDULES -- Again referring to the Work Breakdown Structure (figure 1-14), it will be noted that the tasks are broken down to the third level. The Management Control Plan will break down further, the activity for subtasks to the fourth level. When PERT tells management that a task, an area, or a hardware item has fallen behind schedule, and the behind-schedule condition is serious, a recovery schedule is immediately prepared which breaks down to at least the level below the MCP level, or the fifth level of activity. This recovery schedule programs all activities required to whatever depth necessary to bring the problem back to "on-schedule" condition as rapidly as possible. The recovery schedule is, in essence, an interim schedule which phases in to the detailed schedule and the PERT Network and tells management the earliest possible date at which recovery will be made. It further defines the necessary resources and additional cost required to effect recovery. Recovery schedules generally are internal working documents and are not usually submitted to the customer. However, copies may be furnished to NASA upon request. NASA will, of course, be made aware of the problem and its solution via PERT and the Situation Summary Report. (Refer to figure 1-15.)

1.8.2 PART II- INTEGRATED COST PLAN

1.8.2.1 Scope

The Integrated Cost Plan gives the Program Manager timely financial visibility through a network of discrete cost centers identified to contract end items (CEI) and traceable through the PCTR PERT network explained in Part I. This control is established and maintained from the contract award through the final financial documentation by an orderly plan which utilizes existing Northrop cost collection systems.

Efficient operation of this plan depends upon three logically organized elements.

a) Sales Order/Work Breakdown Structure
b) Northrop Integrated Cost Control System
c) PCTR Management Control Plans

Financial documentation, i.e., Graphical Summary Reports and Financial Management Reports, naturally follow from the outputs of this plan at intervals as required in Exhibit C of the Phase IV Contract.

1.8.2.2 Sales Order/Work Breakdown Structure

All contract work performed at Northrop is assigned a discrete contract number as illustrated in table 1-4. Assignment of the sales order pattern is coordinated with the Cost Accounting organization, Contract Administration, and the performing organization so that a meaningful sales order pattern is developed to monitor and collect costs. Part II of this plan shows a tree of the Work Breakdown Structure for the Phase Change Thermal Radiator Program. By joining this Contract End Item (CEI) Work Breakdown Structure with the contract number, a sales order pattern has been developed which forms the cost collection matrix used to report significant costs against the PERT network. Table 1-4 is a listing of a representative sales order pattern. Implementation of this pattern will allow the PCTR Program to use the Northrop Data Processing Center to gather cost data automatically in a form that can be used to construct financial reports against PERT network elements. This automatic cost collection function is performed by the Northrop Integrated Cost Control System.

1.8.2.3 Integrated Cost Control System

The Integrated Cost Control System (ICCS) provides a dual function on programs such as the PCTR employing PERT. The ICCS is the basic cost accumulation system and is structured to the Sales Order Pattern/Work Breakdown Structure assigned to each contract or operating function. All elements of direct labor,

TABLE 1-4 SALES ORDER PATTERN

7XXX1000	Prototype Unit
7XXX2000	Qualification Unit
7XXX3000	1st Flight Unit
7XXX4000	2nd Flight Unit
7XXX5000	Ground Support Equipment
7XXX6000	Training
7XXX7000	Management and Documentation
	Sub-Basic Sales Order Numbers
7XXXX100	Radiator Experiment
7XXXX200	Observation Experiment
7XXXX300	Support System
7XXXX400	System Integration
7XXXX500	Checkout Console
7XXXX600	Battery Support Unit
7XXXX700	LN_2 Fill System

Task Numbers Representing Organizational Functions

Program Administration	
7XXXXXX10	Supervision
7XXXXXX11	Program Control
7XXXXXX12	Configuration Management
Engineering	
7XXXXXX20	Supervision
7XXXXXX21	Systems Engineering
7XXXXXX22	Systems Design
7XXXXXX23	Technical Integration
Operations	
7XXXXXX30	Supervision
7XXXXXX31	Manufacturing and Procurement
7XXXXXX32	Test
7XXXXXX33	Support
Quality Assurance, Reliability and Safety	
7XXXXXX40	Supervision
7XXXXXX41	Reliability Engineering
7XXXXXX42	Quality Control Engineering
7XXXXXX43	Safety Engineering

material, and other costs are subdivided and categorized by the standard Northrop Chart of Accounts. The types of resources expended on work packages of the work breakdown structure are accumulated by the ICCS from labor distribution time cards, material commitments and disbursements, computer sorted and summed into the proper work package charge number for the PERT Integrated Cost Control System. Since the Phase Change Thermal Radiator Program Work Breakdown Structure has been intimately tied to the Sales Order Pattern, these collected costs form the basis for the financial reports.

The ICCS further provides that all elements of cost are identified to organizational responsibility and the divisional accounting structure. All levels of management are measured by actual costs compared to operating budgets. By means of sorted data output from the ICCS, departmental managers prepare a monthly status of their cost position in the form of an Indicated Final Cost (IFC) report. This report relates the previous month's IFC to current IFC. Budgetary performance gains and/or losses are detailed, changes in statements of work are indicated, and transfers of statements of work, either within a department or between departments, are shown. The IFC reflects cost to date and relates internal operating budgets to department budget objectives. All department IFC reports are incorporated into a monthly report for divisional general managements. This report is the focal point for review of status by program and by department each month.

Internal programming of this system provides for conversion of direct labor hours by charge numbers, by man numbers, and organization into dollars via the current associated rates. Various data sorts are produced that provide detailed and summarized actuals by hours and/or dollars to functional identities. Figure 1-19 shows how the system operates. Correlating direct labor to the Chart of Accounts is accomplished automatically by the computer program through the associated organization number. Indirect labor is picked up from keypunched labor attendance cards, sorted by organization, and distributed as burden to current contracts on a burden center basis.

Material charges originate from two basic sources, purchased parts and basic material. Purchased parts are charged to individual contracts at the time of purchase. Lot buys of material common to several contracts are purchased to an inventory account and subsequently charged out of inventory to

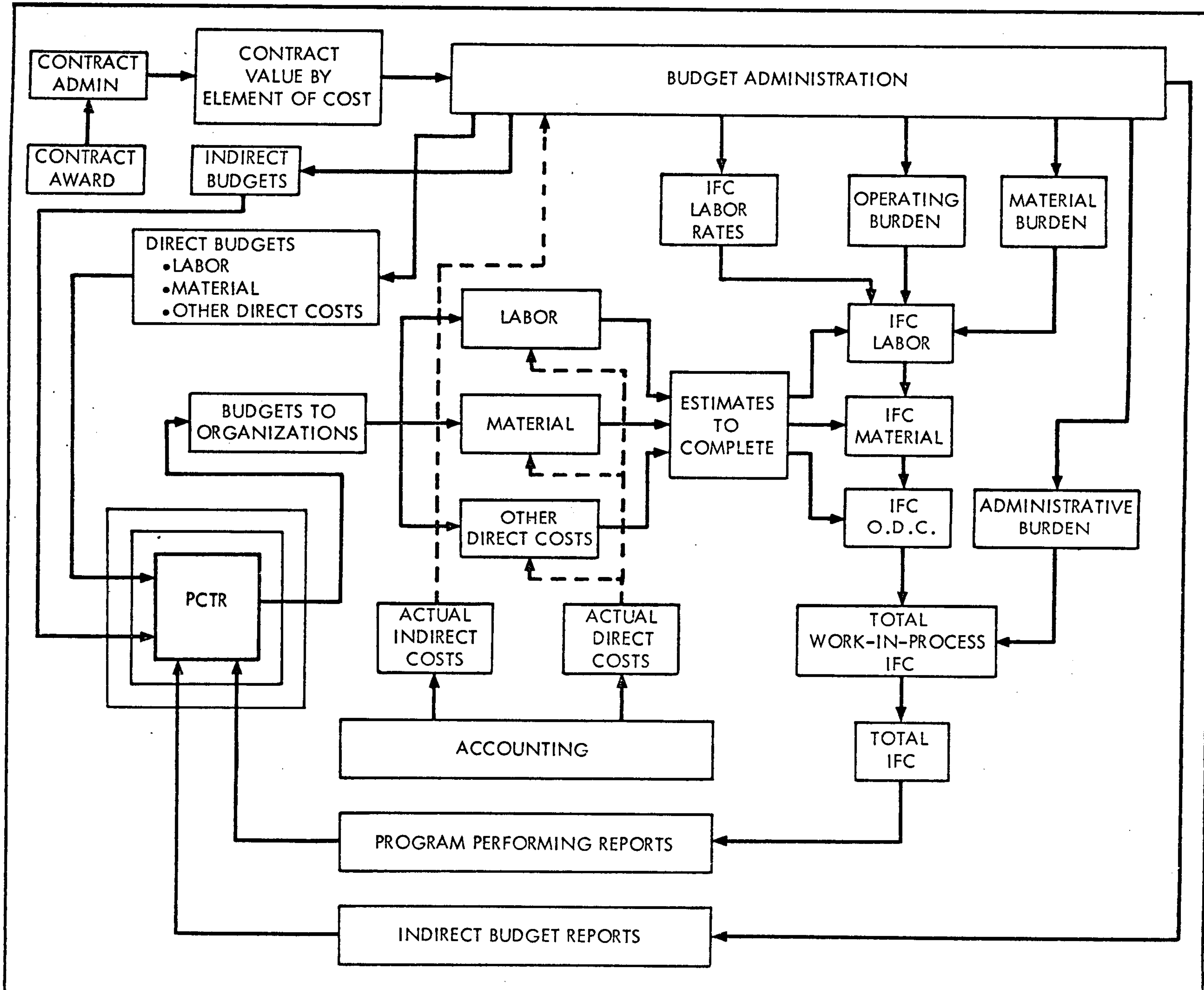


FIGURE 1-19 PCTR PROGRAM RELATION TO NORTHROP'S INTEGRATED COST CONTROL SYSTEM

individual work package charge numbers on an allocated basis related to factory labor.

All charges are picked up, sorted by the Integrated Cost Control System into Work Breakdown Structure charge numbers automatically, and reports printed suitable for incorporation into the desired financial reporting documentation.

1.8.2.4 PCTR Cost Control

PCTR cost control is based upon the cost objectives contained in the Management Control Plans (MCP's). The Cost Plan NSL 67-209 and the Manpower and Funding Plan present the Phase IV cost data. Program cost performance is measured with the MCP cost information as the baseline.

The PCTR Cost Control flow plan is shown in figure 1-20 and should be used as a guide for the following discussion. All cost information is handled by the Program Administration Group.

1.8.2.4.1 BUDGET RELEASE -- Northrop's Finance Department provides the Sales Orders to the PCTR Program upon contract award. The Finance Department also opens the Integrated Cost Control System to accept charges according to the PCTR Sales Order Pattern.

The Program Manager releases the budget to the PCTR organizations through the Program Administration Group. Individual budget authorization is released by an executed Budget Advice Form (figures 1-21 and 1-22). This initial budget release is accompanied by a Direct Cost Chart, figure 1-23, on which is shown the man loading and cumulative cost objective derived from the MCP's.

1.8.2.4.2 PERFORMANCE REVIEW -- Weekly cost information from the Integrated Cost Control System (ICCS) is entered on the Budget Advice forms by the Program Administration Group, compared to the MCP baseline, and issued. A complete set by organization and CEI is submitted to the Manager of the Northrop Systems Laboratories, and to the Program Manager. The Program Manager will point out any significant cost activity. This weekly cycle will continue for the life of the contract.

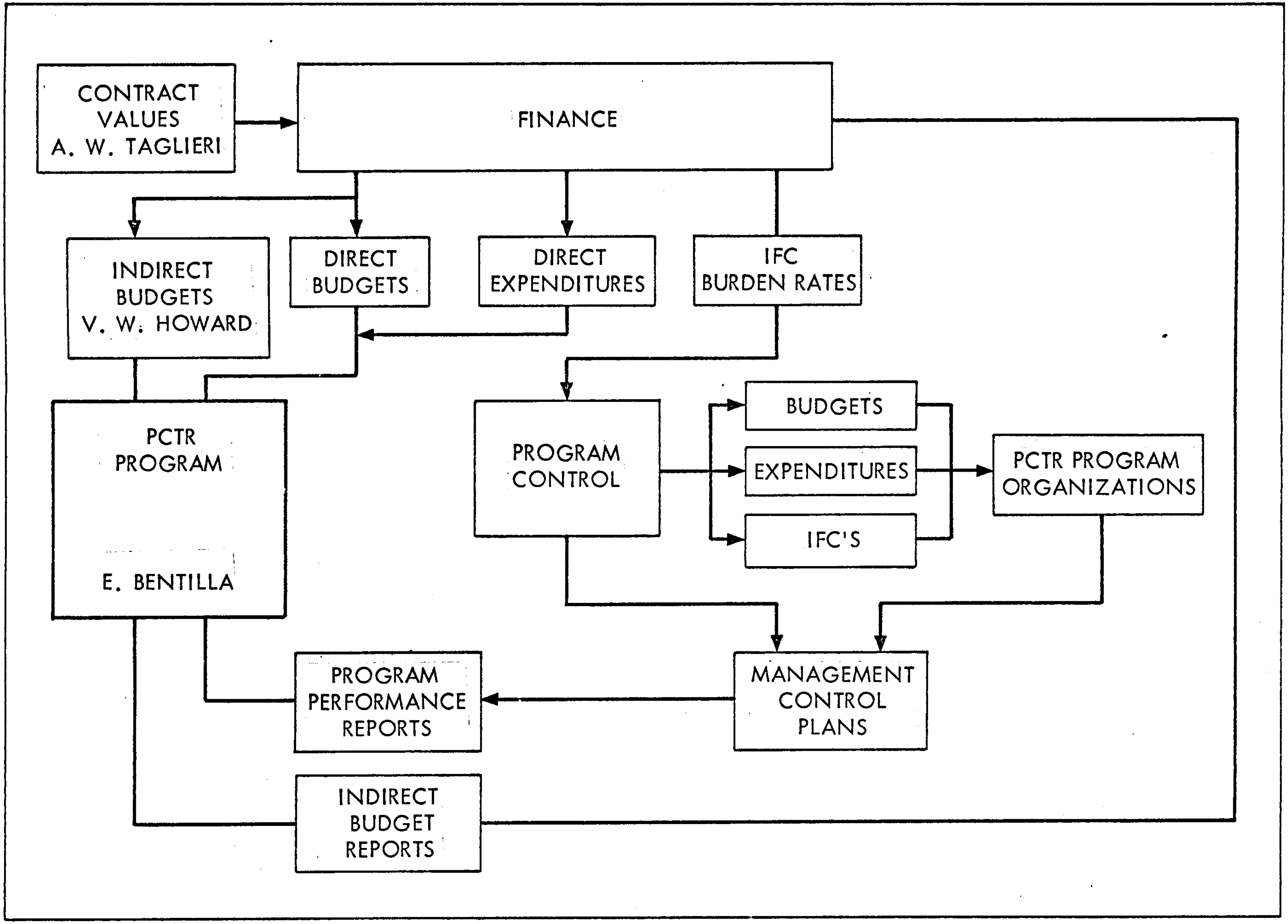


FIGURE 1-20 PCTR PROGRAM COST CONTROL SYSTEM

BUDGET ADVICE

BUDGET DATE ____________

CONTRACT END ITEM ____________________ WEEK ENDING ____________

(SALES ORDER)

		BUDGET		TOTAL TO DATE		THIS WEEK		% EXPENDED	
		HOURS	$	HOURS	$	HOURS	$	HOURS	$
LABOR	7220 DEPUTY MGR								
	7221 CONFIGURATION MANAGEMENT								
	7222 PROGRAM OPERATIONS								
	7230 ENGINEERING								
	7235 SYSTEMS CREW MISSION INTEGRATION								
	7240 TEST, CHECKOUT & OPERATIONS								
	7245 MANUFACTURING OPERATIONS								
	7250 QUALITY ASSURANCE, RELIABILITY & SAFETY								
	TOTAL LABOR								
MATERIAL									
	TOTAL MATERIAL								
ODC	TRAVEL								
	COMPUTER								
	CONSULTANT								
	PURCHASED LABOR								
	TOTAL ODC								
	TOTAL BUDGET								

FIGURE 1-21 CEI BUDGET ADVICE FORM

BUDGET ADVICE ORGANIZATION ______________ WEEK ENDING ______
BUDGET DATE ______

CATEGORY	BUDGET		TOTAL TO DATE		THIS WEEK		% EXPENDED	
	HOURS	$	HOURS	$	HOURS	$	HRS	$
LABOR								
TOTAL LABOR								
MATERIAL								
TOTAL MATERIAL								
ODC								
TOTAL ODC								
TOTAL BUDGET								

FIGURE 1-22 ORGANIZATION BUDGET ADVICE FORM

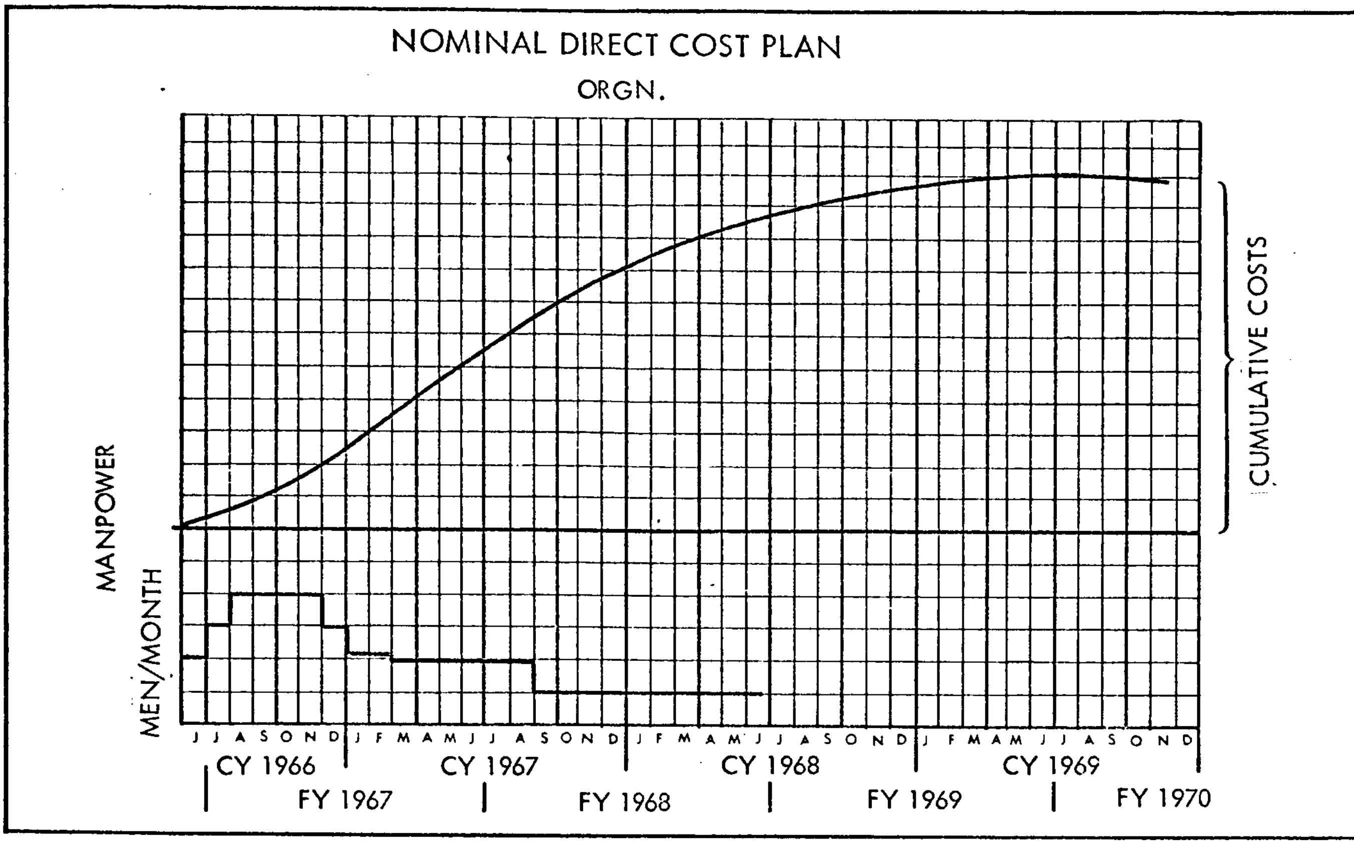


FIGURE 1-23 ORGANIZATION DIRECT COST CHART (WITH NOMINAL CURVES)

Weekly reviews will be held in the Control Room with the cognizant engineers and group chiefs. If any area shows unexpected cost activity, the reviews may be more frequent and specific areas further evaluated.

Each month, a current Direct Cost Chart will be issued to the organizations along with their weekly Budget Advice form so that they are kept abreast graphically with their cost performance.

1.8.2.4.3 BUDGET REVISION -- Upon direction of the Program Manager, the budget of any organization or CEI can be changed by the issuance of a Budget Revision Form (figures 1-24 and 1-25). These forms will fully explain the change and show the proper authorization. Budget changes may result from negotiation, change or scope, or other reasons the Program Manager judges sufficient.

Properly executed Budget Revision Forms will be transmitted to the affected persons, and their associated Direct Cost Charts and Budget Advice Form will be updated to reflect the change.

BUDGET REVISION NOTICE
REVISION DATE ________ SUPERCEDES BUDGET DATED

CONTRACT END ITEM ____________________
(SALES ORDER)

CATEGORY	NOTE	OLD BUDGET		CHANGE		NEW BUDGET	
		HOURS	$	HOURS	$	HOURS	$
LABOR							
MATERIAL							
ODC							

NOTE	REASON AND AUTHORITY

FIGURE 1-24 CEI BUDGET REVISION FORM

BUDGET REVISION NOTICE ORGANIZATION ____________________
REVISION DATE ________ SUPERCEDES BUDGET DATED

CATEGORY	NOTE	OLD BUDGET		CHANGE		NEW BUDGET	
		HOURS	$	HOURS	$	HOURS	$
LABOR							
MATERIAL							
ODC							

NOTE	REASON AND AUTHORITY

FIGURE 1-25 ORGANIZATION BUDGET REVISION FORM

In addition to the budget advice forms, large Direct Cost Charts (figure 1-23), are maintained in the Program Control Room to provide the Program Manager with the needed financial visibility. Additional cost charts are also maintained by Program Control to keep the Program Manager aware of cost status at all times. These charts will be maintained weekly as cost information is available.

1.8.2.4.4 INDICATED FINAL COST (IFC) -- Each month, in conjunction with the preparation of the contractually required financial reporting, the Program Administration Group will prepare IFC's (figure 1-26) with the cognizant engineers. These will be used to prepare the NASA form 533 and will be separately evaluated by the Program Manager to determine what corrective action, if any, is required. This report and the PERT slack time report provides the Program Manager with control visibility. Copies of the report are submitted to the Manager of Northrop Systems Laboratories.

1.8.2.4.5 PCTR COST PLANS -- Complete cost objectives and their distribution are presented in the Phase IV Proposal, NSL 67-209. Upon contract award, complete and detailed cost objectives listed in the MCP's will be issued to the PCTR organizations by the Program Administration Group utilizing the budget advice forms and direct cost charts as outlined in subsection 1.8.2.4.

☐ CONTRACT END ITEM

☐ SECTION

TITLE

ACTUALS AS OF MONTH ENDING

COGNIZANT ENGINEER

SUBDIVISIONS OF WORK AND/OR ELEMENTS OF COST	NOTE	ACTUAL COST TO DATE	% SPENT	EXPENDITURE			BUDGET	INDICATED FINAL COST		BUDGET POSITION	
				THIS MONTH		NEXT MONTH		LAST MONTH	THIS MONTH	UNDERRUN (OVERRUN)	GAIN (LOSS) OVER LAST MONTH
				PREDICTED	ACTUAL						

NOTES

PREPARED BY

FIGURE 1-26 INDICATED FINAL COST REPORT

NSL 67-202

SECTION 2.0

TECHNICAL INTEGRATION PLAN

TABLE OF CONTENTS

TECHNICAL INTEGRATION PLAN

LIST OF ILLUSTRATIONS

TABLE

2.0 TECHNICAL INTEGRATION PLAN

2.1 Technical Integration Plan Objective and Methodology

The objective of the Technical Integration Plan is to provide an optimum plan for accommodating the constraints and requirements of all Apollo System Mission and Crew interfaces with the PCTR Experiments and support subsystems. The first step of the integration methodology to be employed in Phase IV is to define all interfaces. Each interface is then analyzed in detail and the requirements and constraints are identified. The constraints stem from the following guidelines:

a) Adjust to the limitations of astronaut time, safety, and activity available for the performance of experiments.

b) Avoid changes in the Apollo System hardware. The requirements imposed on the PCTR system are determined from

   1. The mission crew and system constraints
   2. The desired performance of the experiments

Therefore, it is necessary to carry out mission, crew and system analysis as well as analysis of the PCTR system and its various subsystems. Once the requirements and astronaut time lines are specified, functional integration has been achieved. The physical integration, however, will require additional analysis of hardware compatibility. Here, the fabrication of mock-ups and test articles are helpful in reaching the design specifications of the prototype/flight models.

Inasmuch as each interface requirement change affects the overall PCTR configuration, the technical integration is essentially a part of the Management Plan. The design adjustments resulting from integration is a reiterative process, each iteration maintaining the desired performance to the greatest extent possible, but more realistically adjusting to interface requirements and constraints. Each iteration maintaining the desired performance to the greatest extent possible, but more realistically adjusting to interface requirements and constraints. Each iteration requires proper documentation of changes as described in the Management Plan Configuration Management Section.

These effects on configuration propagate into other program plans such as the Design Plan, the Manufacturing Plan, the Quality, Reliability and Safety Plan, the Test Plan, the Facilities Plan, the Logistics Plan, the Cost Plan, the Schedule Plan, and Manpower and Funding Plan.

The execution of the Technical Integration Plan thus results in a final updating of all other Program Plans, all such updating stemming from the detailed integration of the PCTR experiments and support subsystem into the Apollo System Mission and Crew Operations.

2.2 Definition of Interfaces

Most of the interfaces have been identified during the course of Phase II and Phase III. These are summarized in table 2-1.

2.3 System Analysis and Specifications

The detailed system analysis of the various interfaces will lead to the specifications for the hardware. Following this methodology has led to the hardware shown in figures 2-1 and 2-2.

2.3.1 HARDWARE COMPATIBILITY

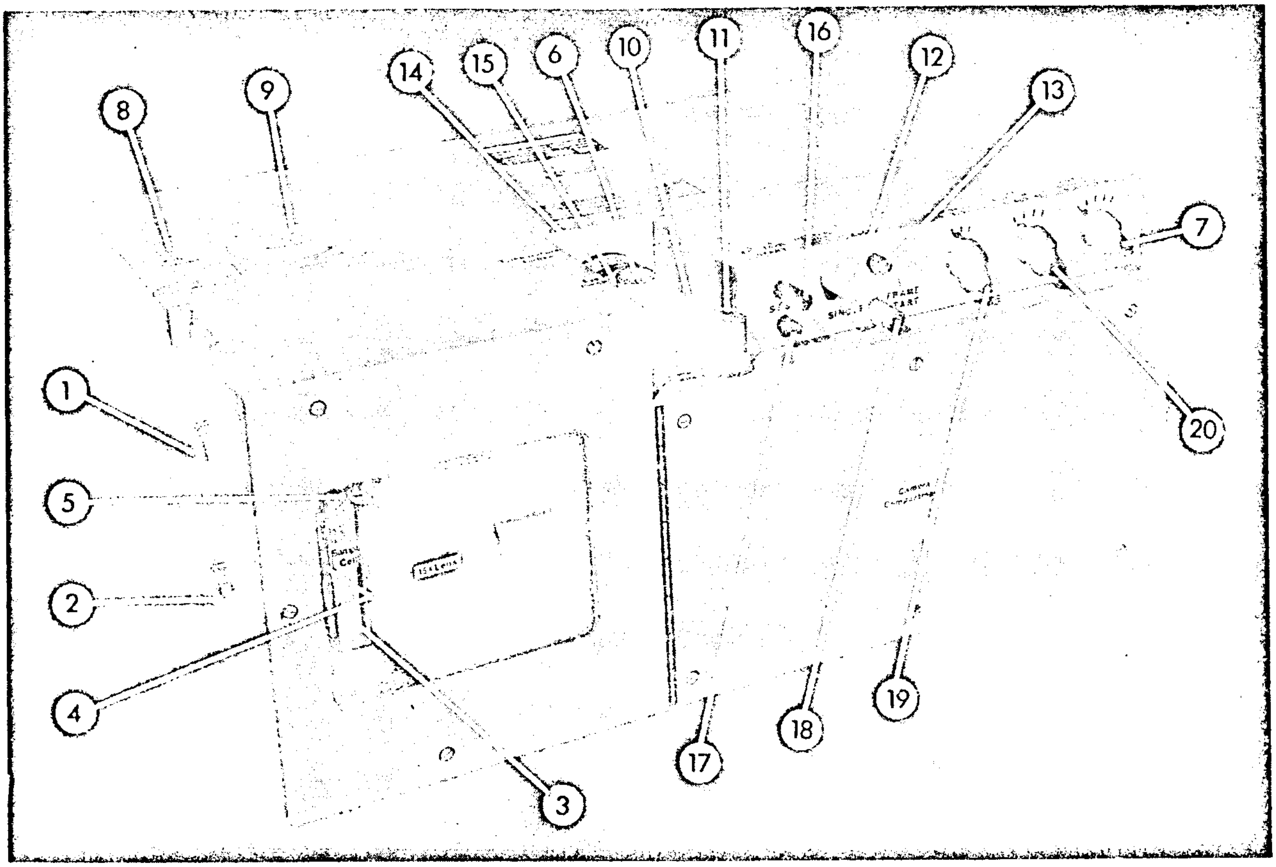
The Observation Unit, PCM Samples, and Tape Recorder Sink 1 are located in the Rock Box Voice of the Apollo CM as shown in figure 2-3. The Battery and Conversion Electronics are located in the Still Camera Void of the Apollo CM.

The Space Radiator Module and the Sink Radiator Module are located in Sector I of the SM as shown in figure 2-4.

These locations are highly compatible with the existing Apollo Hardware, requiring only minor modification of the Rock Box and Camera Voids and only slight modification of the SM Sector I skin.

TABLE 2-1 PCTR INTEGRATION MATRIX

	SPACE RADIATOR	SINK RADIATOR	OBSERVATION UNIT	POWER & CONTROL SYSTEM	LIQUID N_2 SYSTEM	DATA SYSTEM	CM	SM	ASTRONAUT	MISSION
SPACE RADIATOR		Mounted Adjacent Share Data & Power & Control		(1) Supplies Power & Control	Mounted on Same Subframe	Retrieves & Stores Data from Thermistors & Heater Voltage of Space Radiator	Space Radiator Controls Located in CM. Hardwire Interconnection Between CM & SM	Space Radiator Mounted in Sector I of SM on External Mold Line	Initiates & Monitors Expt. EVA Retrieval of Radiator Expt. Module Containing Space Radiator. Notes Time	↙
SINK RADIATOR	Mounted Adjacent			Supplies Power & Control	Supplies Coolant to Sink Radiator	Retrieves & Stores Data from Thermistors & Heater Voltage of Sink Radiator	Sink Radiator Controls Located in CM. Hardwire Interconnection Between CM & SM	Sink Radiator Mounted in Sector I of SM on External Mold Line	Initiates & Monitors Expt. EVA Retrieval of Radiator Expt. Module Containing Sink Radiator. Notes Time	↙
OBSERVATION UNIT				Supplies Power & Control		Retrieves & Stores Temperature Data. Regulates Camera Film Transport	Observation Unit Located in CM Rock Box		Performs Expt. Initiates Film & Thermocouple Sensing. Replaces Samples. Notes Time.	↙
POWER & CONTROL SYSTEM	↗	↗	↗		↙	↙	Supplies Storage for Power & Control System in Camera Void & Rock Box	↙	↙	↙
LIQUID N_2 SYSTEM	↗	↗		Initiates LN_2 Operation & Supplies Power		Data System Monitors LN_2 Cold Plate Temp.		LN_2 Sys. Mtd. in Sector I of SM. Adj. to Sink Radiator Hdwre. Connection from SM to LN_2 Valve Solenoid	Initiates & Monitors LN_2 System	↙
DATA SYSTEM	↗	↗	↗	Supplies Regulated Power & Control	↗		Data Storage & Control Located in CM Rock Box	Rad. Expts. Thermistor Amplifier & Assoc. Elect. Located in CM in Rad. Module	Initiates & Monitors Data Recording Notes Time	↙
CM	↗	↗	Provides Space	↗		↗		Use of Existing Hardwire Interconnectors	Apportions Time Between Experiment Activities With Other SAA Activities	↙
SM	Provides Space & Mounting	Provides Space & Mounting		Hardwire Interconnection From CM to SM	↗	↗	↗		Release Radiator Module from SM	↙
ASTRONAUT	Turns On - Operates Controls & Records Data. Notes Time Maneuvers Direction.	Turns On - Operates Controls & Records Data. Notes Time Maneuvers Direction.	Turns On - Operates Controls & Selects & Retrieves Samples. Observes Micr. Takes Film - Notes Time	Operates Controls Observes Displays	↗	↗	↗	↗		↙
MISSION	Operates During Stable Orbit With Known Attitude History and Sun Angle	Operates During Stable Orbit With Active Period on LN_2	Stable Orbit - Non-Interference with Other Parts of Mission Stored Frozen Samples Near End of Mission	Time of Sample Storage Determining Total Power Requirement	Must be Activated During Early Part of Mission	Return Stored Data With CM	SAA Mission	SAA Mission	Shares Expt. Performance Activities with Other SAA Duties	



CONTROLS 1 THRU 11 FOR OBSERVATION (OBSV) EXPERIMENT ONLY

1. CELL POSITIONER ---------- POSITIONS TEST CELL
2. CELL FOCUS ---------- FOCUSES TEST CELL
3. SAMPLE CELL ---------- CONTAINS TEST MATERIAL
4. THERMOCOUPLE BANK CONTROL KNOB --- POSITIONS THERMOCOUPLES ON TEST CELL
5. TEST CELL LOCK ---------- LOCKS CELL IN TEST POSITION
6. EYE PIECE ---------- MICROSCOPE EYE PIECE
7. OBSV CONTROL ---------- ENCODES DATA TAPE AND SELECTS TEST CELL END THERMOELECTRIC COOLER/HEATER:
   1 = POWER OFF
   2-5 = POWER ON, FUNCTIONS COULD BE CONTROLLED AUTOMATICALLY ON FLIGHT EXP
   2 = BOTH ENDS IN COOLING MODE
   3 = TOP END IN HEATING MODE, BOTTOM END IN COOLING MODE
   4 = TOP END IN COOLING MODE, BOTTOM END IN HEATING MODE
   5 = BOTH ENDS IN HEATING MODE
8. CELL STORAGE ---------- TEST CELL STORAGE (6 CELLS)
9. CELL COLD STORAGE ---------- TEST CELL STORAGE TO MAINTAIN 2 CELLS IN SOLID STATE (WATER AND/OR OCTADECANE)
10. TEMP CONTROLLER NO. 1 ---------- SETS TEST CELL UPPER END TEMP
11. TEMP CONTROLLER NO. 2 ---------- SETS TEST CELL LOWER END TEMP

CONTROLS 12, 13, 22, AND 23 FOR RADIATOR (RAD) EXPERIMENTS ONLY

12. HEATER OVER RIDE ---------- BACK UP TO AUTOMATIC HEATER POWER SHUT OFF
13. CALIB ---------- CALIBRATES READING, TEMP GAGE AND DATA TAPE FOR THERMISTORS

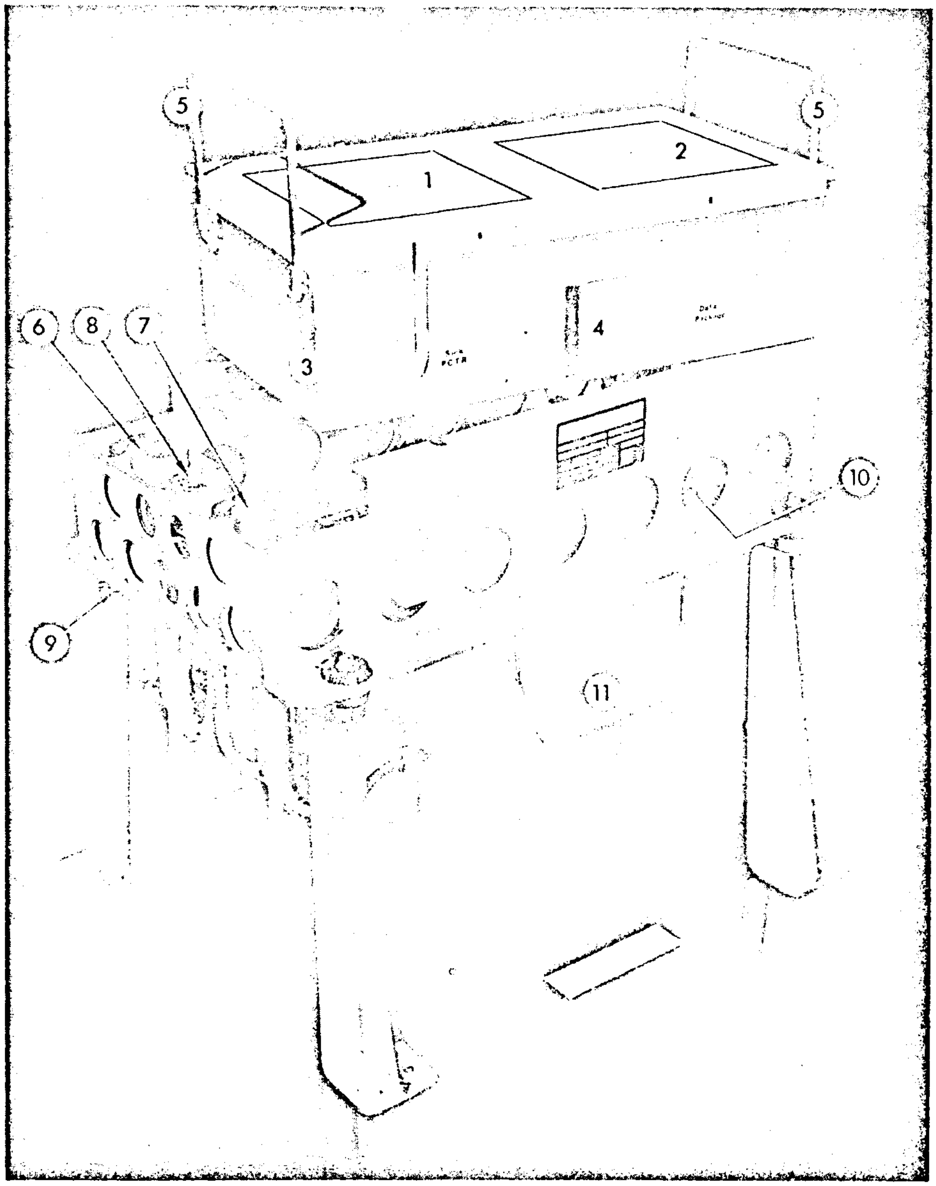
CONTROLS 14 THRU 21 FOR RADIATOR AND OBSERVATION EXPERIMENTS

14. TEMPERATURE GAGE NO. 1:
14.1 OBSERVATION EXPERIMENT ---------- INDICATES SAMPLE CELL UPPER END TEMP
14.2 RADIATOR EXPERIMENTS ---------- INDICATES PHASE CHANGE RADIATOR TEMPS (SPACE OR SINK)
15. TEMPERATURE GAGE NO. 2:
15.1 OBSERVATION EXPERIMENT ---------- INDICATES SAMPLE CELL LOWER END TEMP
15.2 SPACE RADIATOR EXPERIMENT ---------- INDICATES SIMPLE RADIATOR TEMP
15.3 SINK RADIATOR EXPERIMENT ---------- INDICATES LN_2 COLD WALL TEMP
16. DATA CONTROL START:
16.1 OBSERVATION EXPERIMENT ---------- STARTS DATA AND CAMERA SYSTEMS
16.2 RADIATOR EXPERIMENTS ---------- STARTS DATA SYSTEM AND HEATER POWER
17. DATA CONTROL STOP:
17.1 OBSERVATION EXPERIMENT ---------- STOPS DATA AND CAMERA SYSTEM
17.2 RADIATOR EXPERIMENTS ---------- MANUAL STOP DATA SYSTEM AND HEATER POWER (RAD EXPS HAVE AUTOMATIC SHUT-OFF CONTROLS)
18. SINGLE FRAME START:
18.1 OBSERVATION EXPERIMENT ---------- SINGLE FRAME START, DATA AND CAMERA SYSTEMS
18.2 RADIATOR EXPERIMENT ---------- SINGLE FRAME START, DATA SYSTEM
19. EXP SEL ---------- ENCODES EXPERIMENT ON DATA TAPE AND SELECTS EXP CONTROLS:
   1 = SPACE RADIATOR EXP
   2 = SINK RADIATOR EXP (ACTIVATES LN_2 SYSTEM AT FIRST DATA CONTROL START)
   3 = OBSV EXP (SWITCHES POWER TO CELL ILLUMINATOR, OBSV CONTROL AND TEST CELL THERMOCOUPLES)
20. EXP RUN NO.:
20.1 OBSERVATION EXPERIMENT ---------- ENCODES DATA:
   1 = WATER IN LIQUID INITIAL STATE
   2 = OCTADECANE IN LIQUID INITIAL STATE
   3 = OCTADECANE IN SOLID INITIAL STATE
   4 = OCTACOSANE IN SOLID INITIAL STATE
20.2 RADIATOR EXPERIMENTS ---------- ENCODES DATA TAPE AND SELECTS TEST CONDITION:
   1 = 22 WATTS AND INCOMPLETE LIQUEFACTION
   2 = 22 WATTS AND COMPLETE LIQUEFACTION
   3 = 39 WATTS AND COMPLETE LIQUEFACTION
   4 = 55 WATTS AND COMPLETE LIQUEFACTION

FLIGHT EXPERIMENT CONTROLS NOT SHOWN ON MOCK-UP

21. MASTER POWER SWITCH ---------- NOT SHOWN ON DEVELOPMENT MODEL, SUBSTITUTED BY POWER SUPPLY SWITCH
22. HEAT SHIELD EJECTION SQUIBS SWITCH --- BLOWS OFF HEAT SHIELD PRIOR TO RAD EXP
23. LN_2 SUPPLY LINE CUTTER SQUIB SWITCH --- ACTIVATES TUBE CUTTER SQUIB FOR EVA RETRIEVAL OF RAD EXP MODULE

FIGURE 2-1 PHASE CHANGE THERMAL RADIATOR FLIGHT EXPERIMENT CONTROLS



1. SPACE PHASE CHANGE RADIATOR
2. SPACE SIMPLE RADIATOR
3. SINK PHASE CHANGE RADIATOR
4. RADIATOR EXPERIMENT DATA PACKAGE
5. RADIATOR EXPERIMENT MODULE EVA RETRIEVAL HANDLES
6. LN_2 FILL VALVE
7. LN_2 FLOW & VENT VALVE
8. LN_2 FILL PORT
9. LN_2 SUPPLY LINE CUTTER
10. ELECTRICAL DISCONNECT
11. LN_2 STORAGE TANK
12. RADIATOR EXPERIMENT LAUNCH HEAT SHIELD NOT SHOWN

FIGURE 2-2 RADIATOR EXPERIMENT MODULE WITH FLIGHT TYPE LN_2 SYSTEM & SUPPORT STRUCTURE

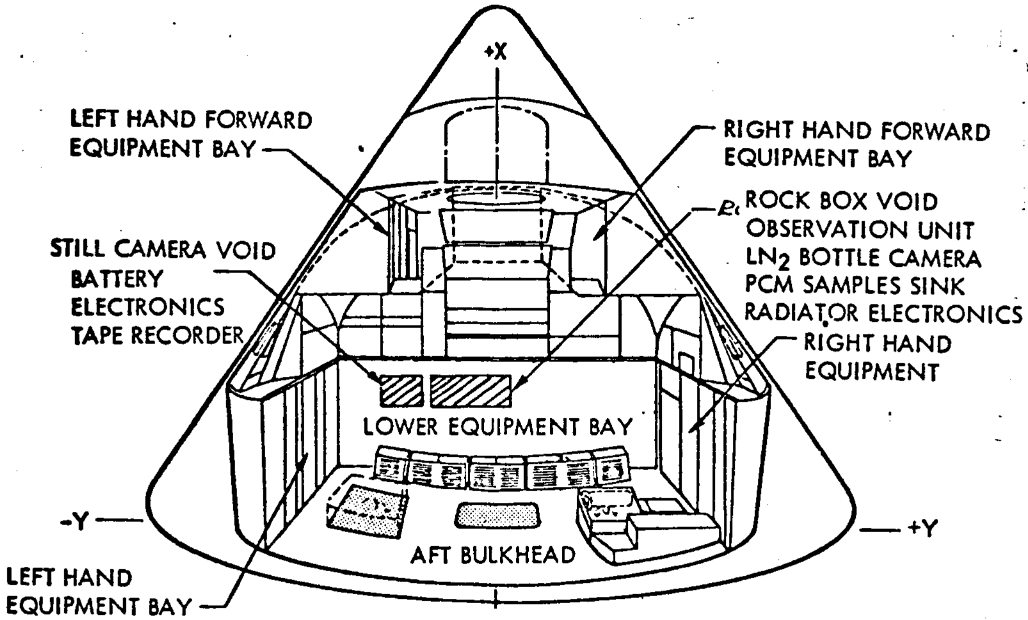


FIGURE 2-3 APOLLO CREW COMPARTMENT, INT VIEW FROM -Z AXIS

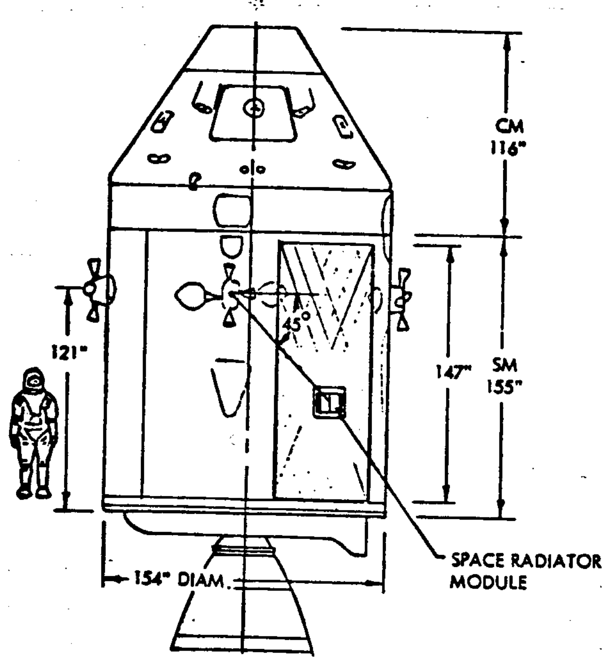


FIGURE 2-4 SPACE RADIATOR LOCATION IN SERVICE MODULE

2.3.2 PROTOTYPE TEST ARTICLE AND MOCKUP REQUIREMENTS

As an aid to achieving successful integration of the (a) Observation Unit and (b) Battery, Electronics and Tape Recorder into the Apollo Command Module, Northrop will make use of its full scale mockup of the Apollo Command Module. This mockup is presently available within the facilities described in the Facilities Plan. The mockup is complete to the extent of the Rock Box and still camera void spaces anticipated for use in housing the above parts of the PCTR experiments.

A mockup of that portion of the SM used to house the Radiator Module will also be fabricated. This mockup will be more concerned with the simulation of the EVA retrieval operation and the achievement of astronaut safety and ease of operation in the design.

The prototype Observation Unit will have been designed and fabricated within the requirements of providing a means of advancing all samples without introduction of inertial forces equivalent to objectionable levels of gravity force magnitude. The requirements in this respect will be the result of trade studies involving astronaut performance with various slow advancement mechanisms and ability of astronaut to execute experiments early. Consideration will be given to use of small accelerameter to measure equivalent g-forces injected by all movement mechanism.

2.4 Mission and Crew Analysis

The gross mission definition provides a basically desirable framework within which to perform the PCTR Experiment. The essential mission characteristics are as follows:

Phase Change Thermal Radiator Flight Experiment will be deployed into an earth orbit by manned Apollo/Saturn vehicle.

The Launch Vehicle will be a Saturn IB booster consisting of the following:

S-IB first stage

S-IVB second stage and instrumentation unit

Apollo spacecraft consisting of:

Service module

Command module

Typical Mission Parameters-Mission 217

Launch Date	Late 1969
Launch Location	Pad 34 Cape Kennedy
Altitude	370 KM(200 nm) circular
Inclination	28.5 degrees
Duration	14 days
Orbit Period	Approximately 92 minutes
Shadow Time	Variable (dependent on launch time)

The gross mission operation sequence constraining the experimental operations are:

Preflight Installation and Checkout
Launch and Boost into Low Earth Orbit
S-IVB/SC Separation
SM Boost into Final Mission Orbit
Orbit and Apollo Systems Checkout
PCTR Experiment Operation
EVA to Recover Space Radiator Module
CM/SM Separation
CM Reentry and Recovery
Experiment Removal from CM

2.4.1 CREW COMPATIBILITY

The total desired experiment operation procedures are as follows:

2.4.1.2 Pretest

Activate heat shield ejection squib switch

Note: Run sink radiator experiment first to assure adequate LN_2 supply.

2.4.1.3 Sink Radiator Experiment

1. Turn master power on.
2. Set exp sel to 2.
3. Log vehicle G & N digital time.
4. Set exp run No. to desired test condition (1, 2, 3, or 4). (The sink radiator experiment runs, 1, 2, 3, and 4 could be programmed

to run consecutively to minimize the LN_2 storage requirement and astronaut monitoring time for sink radiator exp).

5. Push data control start.
6. Push calib and observ temp gages No. 1 and No. 2.
7. Monitor heater override light (in button) and temp gage No. 2. Observe heater override light on when LN_2 sink reaches exp start temperature.
8. *Monitor temp gage No. 1 and heater override light (in button). Push heater override if automatic system does not function at proper temperature.
9. *Monitor temp gage No. 1 and data start system light (in button). Push data stop if automatic system does not function at proper temperature.
10. Complete sink radiator exp run sequence (1, 2, 3, and 4) by returning to step 4 if system is not automated. Proceed to next exp or turn master power off.

2.4.1.4 Space Radiator Exp

1. Turn master power on.
2. Set exp sel to 1.
3. Log vehicle G & N digital time.
4. Set exp run No. to desired test condition (1, 2, 3, or 4).
5. Push data control start.
6. Push calib and observe temp gages No. 1 and No. 2.
7. *Monitor temp gages No. 1 and No. 2 and heater override light (in button). Push heater override if automatic system does not function at proper temperature.
8. *Monitor temp gage No. 1 and data start system light (in button). Push data stop if automatic system does not function at proper temperature.

*Automatic shut off of the radiator heater power and data system are controlled by a primary and backup thermistor. Manual override is the second backup control of system shut off.

9. Complete space radiator exp run sequence (1, 2, 3, and 4) by returning to step 4. Proceed to next exp or turn master power off.

2.4.1.5 Post Test

1. Activate LN_2 supply line cutter squib switch.
2. Perform EVA to retrieve radiator exp module.

2.4.2 OBSERVATION EXPERIMENT - PRELIMINARY OPERATIONAL PROCEDURE

1. Select and place test cell in experiment and lock. Position thermocouple bank.
2. Turn master power on.
3. Set exp sel to 3.
4. Set exp run No. to desired test material (1, 2, 3, or 4). The following steps are typical for a material in liquid initial state. For a material in solid initial state, the procedures are similar except melt fronts are established prior to fusion fronts.
5. Turn cell positioner to zero travel and turn focus knob to cell center line stop.
6. Log vehicle G & N digital time.
7. Initial cool down to establish a liquid/solid interface and super cooling effects:
   7.1 Set temp controllers No. 1 and No. 2 to desired temperature. (Set OBSV control to proper position if system is not automated).
   7.2 Monitor temp gages No. 1 and No. 2.
   7.3 Observe crystal formation in eyepiece.
   7.4 Take single frame pictures and data as desired, single frame start/data stop.
8. Stabilize liquid/solid interface by setting temp. controllers No. 1 and No. 2 at melt pt.
9. First fusion front velocity:
   9.1 Set temp controllers No. 1 and No. 2 to desired temperature. (Set obsv control to proper position if system is not automated).

9.2 Maintain liquid/solid interface in view with test cell positioner.

9.3 Take motion pictures and data on an automatic basis, data start/data stop.

10. Stabilize liquid/solid interface by setting temp. controllers No. 1 and No. 2 at melt pt. and repeat 7.3 and 7.4.
11. Establish second fusion front velocity by repeating steps 9.1 to 9.3.
12. Stabilize liquid/solid interface by repeating step 10.
13. Establish a melting front velocity by repeating steps 9.1 to 9.3.
14. Stabilize liquid/solid interface by repeating step 10.
15. Place cell in storage.
16. Repeat 1 thru 15 or turn master power off.

2.4.3 CREW COMPATIBILITY AND TRAINING

The Crew participation to carry out these procedures is summarized as follows:

1. Observation unit removed from Rock Box
2. Perform pretest functions

Experiment Operation

1. Initiate and monitor radiator testing
2. Record G & N time data
3. Operate observation unit

Experiment Retrieval

EVA to retrieve space radiator module

The Crew training required is summarized as follows:

1. Thorough pre-flight training regarding experiment theory and operation.
2. Training to establish ability to override automatic operation sequence if astronaut senses a change to manual operation will result in better data.
3. EVA training in regard to releasing radiator package from SM skin and protecting radiator surfaces until unit is stored in CM.

2.4.4 RELIABILITY AND SAFETY PLAN

As indicated in Section 2.4.1 all astronaut activity described above is subject to review for safety.

Plans relating to the achievement of reliability and safety in the overall system, crew and mission integration will be found in the Quality Assurance, Reliability and Safety Plan.

NSL 67-203

SECTION 3.0

DESIGN PLAN

FOREWORD

This PCTR Flight Experiment design plan follows the general guidelines of the subject contract (NAS 8-20670) Article I, Section 4, Phase IV. Several of the Design Plan articles are detailed in the other plans to avoid repetition. The Management Plan (NSL 67-201), Cost Plan (NSL 67-209), Manpower and Funding Plan (NSL 67-211), and the Master End Item Specification, MEI, (NSL 67-214) include the details on program reviews, tasks, cost, manpower requirements, and hardware specification.

TABLE OF CONTENTS

DESIGN PLAN

LIST OF ILLUSTRATIONS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

3.0 DESIGN PLAN

3.1 Introduction

Thermal control of equipment and material using phase change materials is a well known concept. A recent study conducted by Northrop for NASA/MSFC has demonstrated the feasibility of this technique for spacecraft temperature control. In fact, a thermal radiator using a phase change thermal radiator is planned for one of the Apollo missions aboard the Lunar Excursion Module. However, to date, all experimentation using phase change materials to control component temperatures have been conducted in the one g environment of earth.

A zero g flight experiment is planned which will repeat selected portions of the work done with phase change materials under one g conditions. The experiment will be flown aboard an Apollo spacecraft in an earth orbit. The experiment objectives are twofold in nature. First, the space radiator packaging concept developed during the previous study is to be tested under actual space environmental conditions (zero gravity, hard vacuum) and variations in solar radiation input. Second, supercooling and solidification of three phase change material samples will be studied and photographed under near laboratory conditions while in a zero gravity condition.

This report presents a design plan developed through the definition of the required flight hardware.

3.1.1 PRODUCT DESCRIPTION

Many spacecraft temperature control applications rely on passive techniques without the use of expendables. All the heat rejection from a space vehicle using this passive technique must be thermally radiated at relatively low temperatures. Phase change materials can be used to store the energy dissipated at the high power conditions at relatively constant temperature. The stored energy can then be radiated to space continuously at the same equipment temperature level.

In addition a thermal control design incorporating phase change materials could be used in the conservation of thermal energy for long term missions to planets with cold environments. Waste heat energy can be stored in phase change materials during operational periods; this energy would supplement heat lost during dormant periods at relatively constant temperature.

The energy per unit weight available with practical phase change materials (normal paraffins, for example) is two orders of magnitude greater than the heat absorption capabilities of spacecraft structure (resulting from the product of allowable structural and component temperature ranges and material specific heat). On the other hand, the energy per unit weight available with phase change materials is one order of magnitude less than the heat of vaporization of water. The simplicity of the solid to liquid phase change system, which is completely passive and regenerable, exhibits a definite advantage for specific applications. Phase change materials can be incorporated with active systems to improve overall system efficiency and reliability.

A research and development study on thermal control through the use of phase change, fusible materials for NASA/MSFC, has demonstrated the feasibility of the hardware required to accomplish this technique for spacecraft temperature control.

The technical approach used to implement the experiment consists of a modular concept involving both the actual experiment hardware and its support units. The overall experiment itself uses three (3) sensing units; an observation unit, a sink radiator and a space radiator. These sensing units are supported by a power and control system, a liquid nitrogen supply and a data system.

3.1.1.1 Observation Experiment

An observation unit operated inside the Apollo Command Module will be used to study the influence of zero gravity on the solidification process and the supercooling required to initiate and control crystal growth. Three experimental phase change materials have been selected for study in the observation unit that will correlate the radiator experiment data and expand knowledge of the basic phenomena under zero g laboratory conditions. Six samples of the three materials will be placed in orbit in their room temperature states and returned to earth for further study in a completely crystallized (solid) state.

In order to obtain the most meaningful data along with well developed crystal samples for later earth study, the observation unit experiment will be conducted by a member of the Apollo crew who will be completely trained not only in the physical operation of the device, but also in excercising a maximum degree of judgement regarding experiment operation. However, the observation unit operation sequence is designed to minimize interference with the astronaut's Apollo mission duties.

The successful operation of a phase change thermal radiator is predicated on crystal growth being obtained each time sufficient heat is removed from a melt. A degree of supercooling is inherently necessary for the nucleation and growth of crystals, although the amount of supercooling required depends upon the particular phase change material and the heat transfer via the environment surrounding the material. The best method to reduce the effects of supercooling in a material which normally tends to supercool is to insure that the original crystalline structure of the material never completely melts. This assures that a minimum crystalline structure will be present in the melt to nucleate the solid crystalline phase again as heat is removed. It is not certain that in an actual space application (zero g) only, partial melting of the solid material will occur. Therefore, present thermal control designs must incorporate, based on one g data, phase change materials which supercool only slightly as a result of their inherent nature or as a result of seeding with substances which assist in initiating the nucleation and growth of crystals.

Material choices made on the basis of one g data have been encouraging. Schafer and Bannister (NASA/MSFC) have reported that the calibration of thermocouples with hexadecane ($C_{16}H_{34}$) is continously being carried out in space with an observed supercooling of 1°K or less. Melting and resolidification are apparently taking place repeatedly over many cycles.

Nucleation and crystal growth are complex phenomena whose mechanisms under weightless conditions are difficult to predict. The observation unit will enable an astronaut to measure supercooling temperatures and to record on film for later study on earth the solidification of three typical phase change materials as it occurs under zero g conditions. Data concerning crystal growth rate, size and habit, temperature history during crystallization and convectionless heat transfer in the liquid will be obtained and correlated with data obtained from analogous experiments performed on earth. In addition, mechanical and optical properties of crystals grown under zero g conditions will be determined and correlated during post-flight analysis.

3.1.1.2 Radiator Experiment

Two separate radiator experiments will be used to evaluate the Phase Change Thermal Radiator concept, system performance, and phase change material behavior in the zero gravity space environment. The space radiator sensing unit is essentially a combination of a prototype spacecraft phase change thermal radiator and a simple calibration radiator. Both units, which are mounted to a common support assembly, will present identical radiating surfaces to the deep space heat sink under zero g and vacuum conditions. However, one unit will contain a phase change material (octacosane) in a honeycomb package bonded to its back side, while the other unit will simulate the first in mass. By operating a calibration radiator sensing device with the same surface coating, space environment exposure, view angle, etc., a direct comparison of the performance improvement obtainable with a phase change material radiator can be made. Both radiators will experience the same surface coating degradation and thereby experience a similar increase in absorption of solar energy. In other words, radiator surface property changes due to environment will act equally on both radiators thereby minimizing the surface coating effect.

The second sensing unit is an exact duplicate of the space radiator with fusible material package. This unit, termed the sink radiator, will radiate to a liquid nitrogen cold sink. Both the sink radiator and its cold sink will be isolated by a hard vacuum so as to eliminate the effects of the convection mode of heat transfer between elements. Further, the radiator itself will be suspended in such a manner that conduction heat transfer will be minimized and monitored.

The sink phase change materials radiator provides a means for isolating the effects of zero gravity on the heat transfer in the aluminum honeycomb-phase change material-void volume matrix. In addition, the variation due to zero gravity on required supercooling to initiate resolidification will also be isolated.

3.2 Design

3.2.1 DATA

3.2.1.1 Observation Experiment

The experiment procedures have been formulated to enable crystal growth data to be obtained under zero g conditions. The apparatus has been designed for compatibility with the Apollo vehicle, mission and personnel. Astronaut participation time and significant data have been the primary design guidelines.

The selection of the phase change materials that will be investigated in orbit was accomplished while considering the scientific and engineering objectives versus weight, power, volume, data, mission and experiment duration relationships. Ideally, it is desirous to investigate sample materials which are of value from a basic scientific standpoint as well as for evaluation and verification of functional capabilities of a thermal radiator in the space environment. The approach was to include among the samples: a) one which is commonly used for thermal control in space applications, b) one which has been investigated from a basic standpoint, and c) one which shows promise for this application as indicated from previous investigations. Based on these criteria, three sample materials have been selected and will be tested as follows in table 3-1.

TABLE 3-1 MATERIAL PROPERTIES

Material	Melting Point °C (°F)	Heat of Fusion (Btu/lb)	Cal/g
Water (H_2O)	0 (32)	143.6	79.7
Octadecane ($C_{18}H_{38}$)	27.8 (83)	105	58.4
Octacosane ($C_{28}H_{58}$)	62 (142)	109	60.5

The water samples will be studied in the observation unit in as high a purity as possible. In addition, octacosane and octadecane will also be studied in the "technical" purity most readily available. The use of very high purity water (NBS or API standard samples) allows comparison with scientific data obtained by a wide variety of investigators on earth. The experiments on "technical" grade octadecane will yield data suitable for design calculations involving actual flight systems. "Technical" purity octacosane samples will also be included that will be prepackaged with 20 percent of the volume void of liquid or solid phase change material. These samples will simulate the actual radiator packaging concept. Table 3-2 summarizes the selected mix of materials that will be studied in the observation unit.

One sample of each of the three materials will be studied in the observation unit in the following order:

1) Water
2) Octadecane
3) Octacosane

TABLE 3-2 OBSERVATION UNIT SAMPLE MIX

Material	High Purity (NBS or API) Standard Sample	Technical Grade	Technical Grade with 20 Percent Void*
Water	2		
Octadecane		2	
Octacosane			2

* No attempt will be made to precondition any of the six samples before each is tested in the observation unit. In all cases, the water samples (melting point = 0°C) will be in liquid form. State of the octadecane will be either liquid or solid since its melting point (28°C) falls within the 15°C - 32°C temperature spread expected for the Command Module during earth orbit. The octacosane will in all cases be in the solid form since its melting point (61°C) is well above even the 43°C maximum temperature expected for the Command Module interior.

By studying this selection of materials, two kinds of determinations are performed:

1) To insure the absolute minimum number of nucleation and growth centers, solidification will be studied in supercooled liquid water of the highest purity.

2) To provide a comparison with (1) above concerning the concentration of residual nuclei in a liquid which has been melted under zero gravity condition, solidification will also be studied in supercooled liquid samples with prior solidification history. Both octadecane and octacosane fall in this category with octacosane in the solid state before study and octadecane in either solid or liquid state depending on the Command Module ambient temperature just before the observations are made.

Correlation of the rate of supercooling, the amount of supercooling observed, and the rate of crystal growth will provide valuable basic information regarding nucleation and crystal growth under the zero g environment. The actual run sequences for the observation unit will be completely defined before the experiment is conducted in orbit. The astronaut operator will have the option and capability to change the sequence of operations as he desires in order to obtain the most meaningful data.

The basic design criteria was determined by performing a parametric analysis, assuming constant thermophysical properties, for the selected fusible materials. The parametric analysis was made using the following parametric equations:

$$\Delta T = T_{cp} - T_{melt} = .745 \left[(q/A)^2 \, \theta \cdot \frac{1}{kPH^{.944} \, C_p^{.056}} \right]^{.947}$$

$$\Delta X = .837 \left[(q/A)^{.927} \, \theta \cdot \frac{(kcp)^{.073}}{PH^{.927}} \right]^{.931}$$

Legend:

H = Heat of fusion (Btu/lb)

P = Density (lb/ft^3)

C_p = Specific heat (Btu/lb-°F)

q/A = Heat rate per unit area ($btu/hr\text{-}ft^2$)

k = Thermal conductivity (Btu/hr-ft-°F)

θ = Time (hrs)

ΔX = Melt thickness (ft)

T_{cp} = Temperature at liquid face (°F)

T_{melt} = Melt temperature (°F) (Temperature at liquid-solid interface)

Assumptions:

1) Constant heat input
2) Material properties constant and at melt point
3) Slab at time zero is at T_{melt}
4) Zero heat conducted through solid
5) Zero connection

The temperature parameter (ΔT) can be used to calculate the temperature change across the liquid melt layer versus heat rate per unit area and the melt thickness parameter (ΔX) provides the thickness of the liquid layer as a function of time.

The results are shown on figures 3-1 for water, 3-2 for octadecane, and 3-3 for octacosane. A parametric curve of solid/liquid interface velocities was determined for constant melt thickness and constant heat inputs and is shown in figure 3-4.

Using the above parametric curves, an experiment was established which would:

a) Furnish desirable data.
b) Be of reasonable duration.

The established test will accomplish the following for:

Water and Octadecane

a) Test two fusion front velocities.
b) Test up to two supercooled conditions.
c) Test one melting front velocity.
d) Provide recorded and observed data and crystals for further analysis.

Octacosane

a) Test two melting front velocities.
b) Test up to two supercooled conditions.
c) Test one fusion front velocity.
d) Determine a void location in liquid octacosane under zero g conditions.

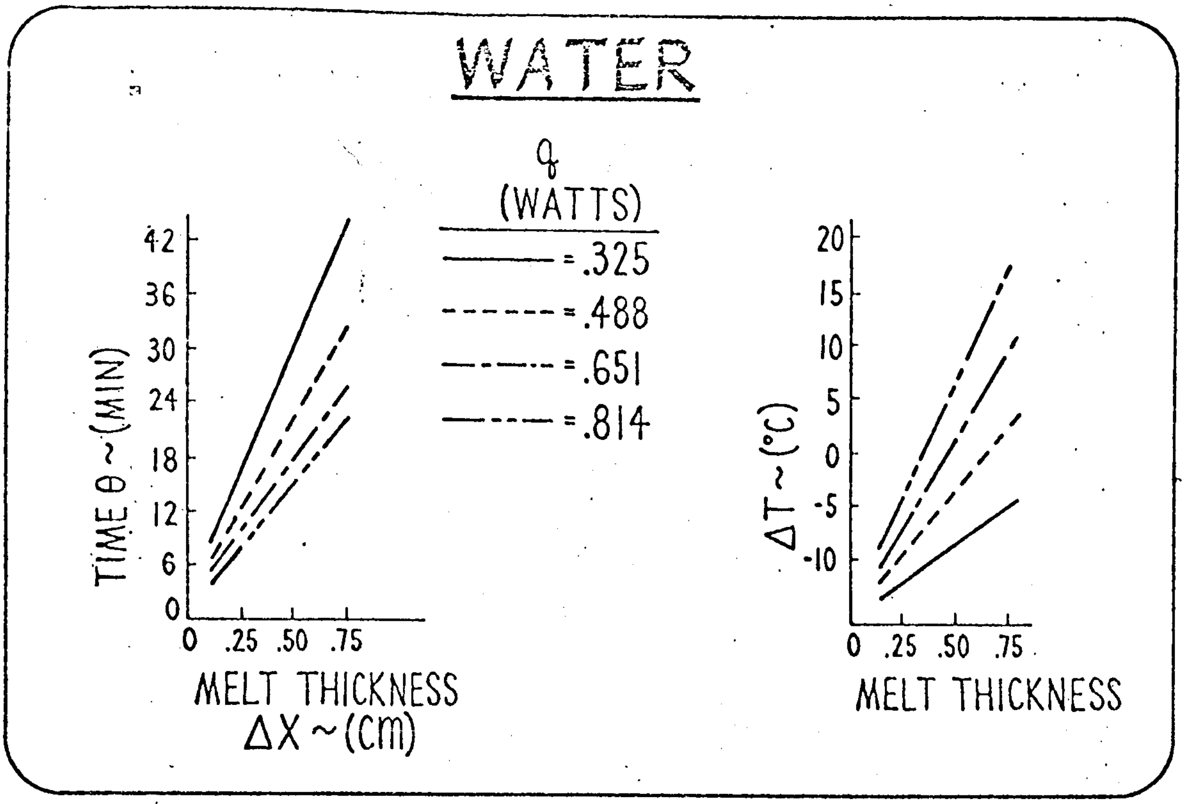


FIGURE 3-1 WATER MELT CHARACTERISTICS

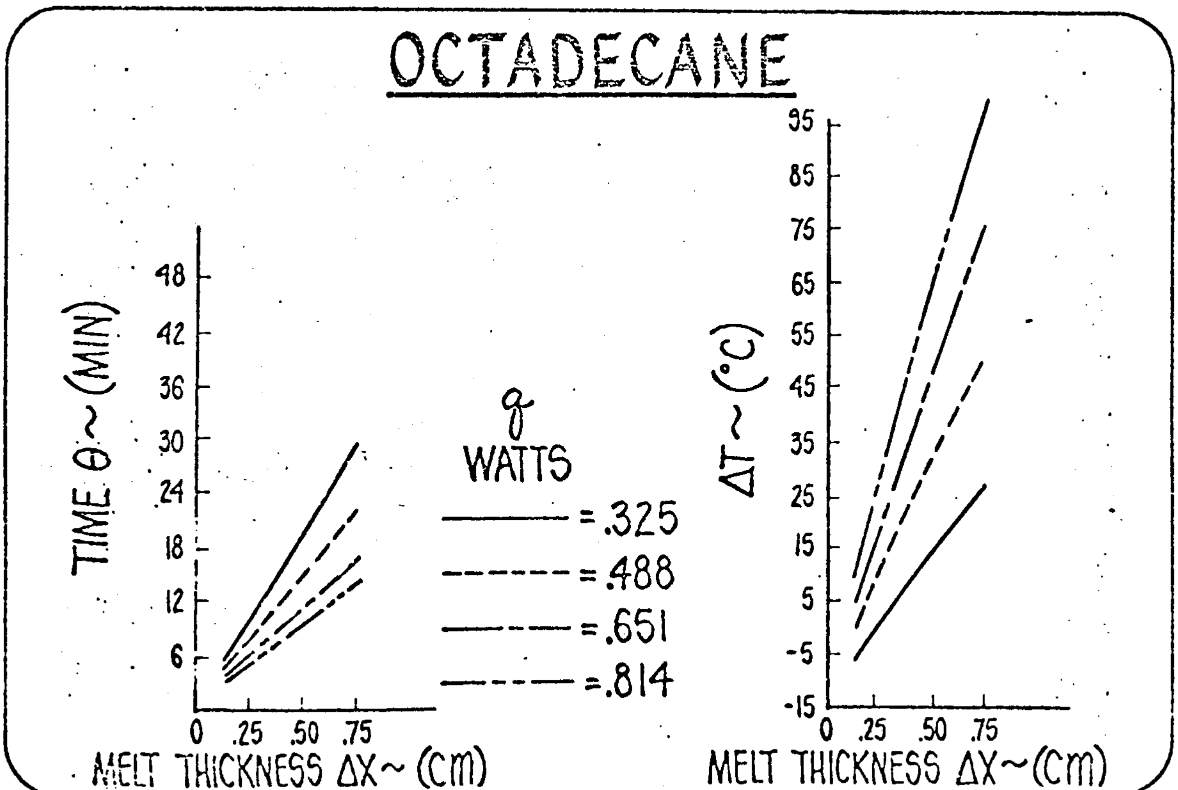


FIGURE 3-2 OCTADECANE MELT CHARACTERISTICS

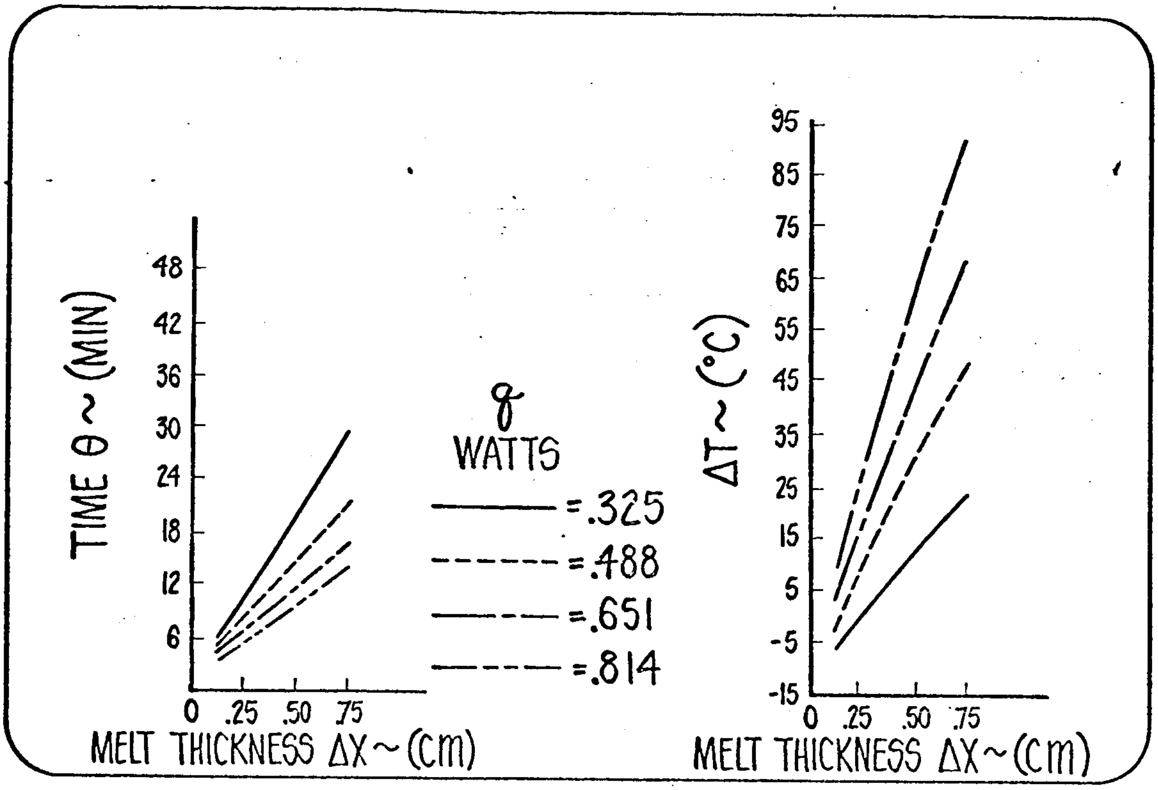


FIGURE 3-3 OCTACOSANE MELT CHARACTERISTICS

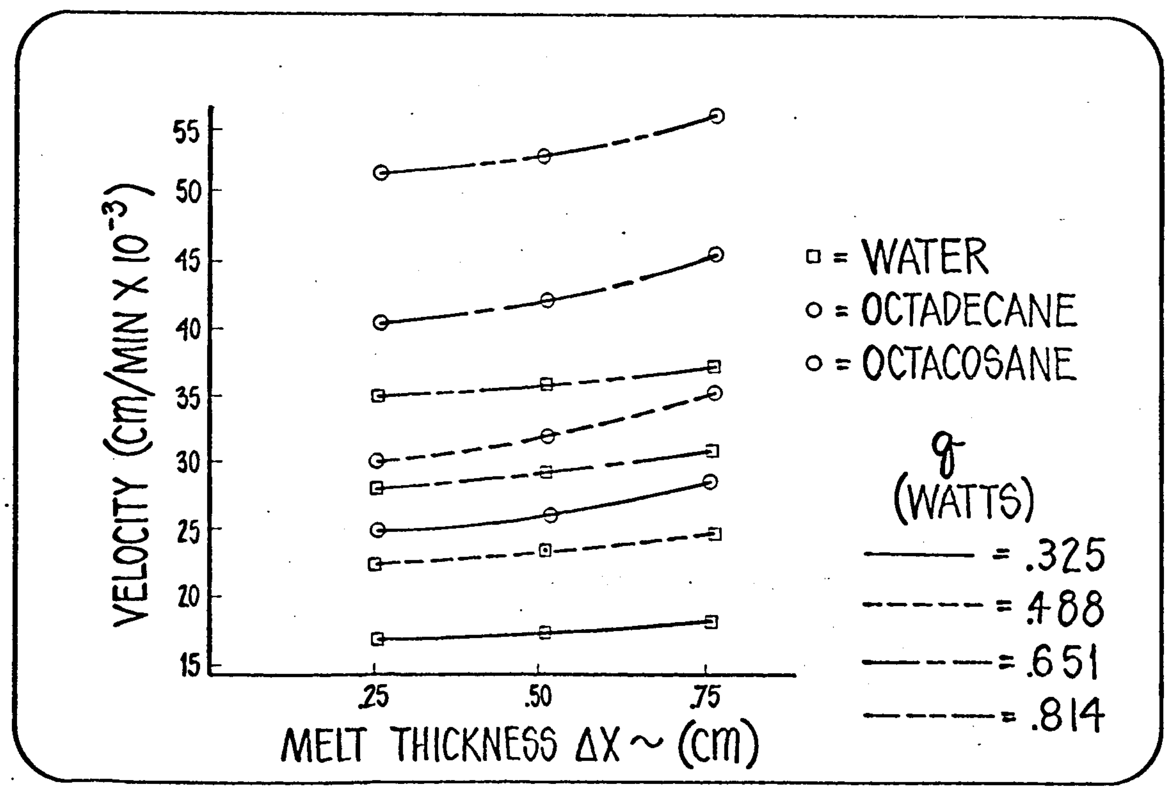


FIGURE 3-4 SOLID/LIQUID INTERFACE VELOCITIES

e) Test interaction of a fusion front with a void.

f) Provide recorded and observed data and crystals for further analysis.

As shown in figure 3-5, the tests will be accomplished in a total experiment average time per cell tested of 106 minutes (1 hour, 46 minutes).

Test Sequence - The following figures show the actual time, control setting, heat input, interface front velocity, interface distance traveled, camera sequence and event time history for each test material:

Test Material	Figure
Water in liquid initial state	3-6
Octadecane in liquid initial state	3-7
Octadecane in solid initial state	3-8
Octacosane in solid initial state	3-9

Although the test sequence is similar for the three test materials, testing of octacosane is the more involved.

The four major phases of the test of octacosane are shown in figure 3-6. Initially, the test cell will contain solid octacosane to a depth of 1.860 cm. The rest of the cell will be a void. By proper application of heat, two melt front velocities will be tested. This will result in a liquid/solid interface .711 cm from the top. The rest of the solid will then be melted. In zero gravity, the void volume is assumed to be an ellipsoid configuration in the liquid. The shape of the ellipsoid is anticipated to be of the same aspect ratio as the inside of the test cell. This results in the top and bottom of the ellipsoid being .245 cm from the top and bottom of the test cell. A fusion front will then be established so as to fuse through the .254 cm of liquid and interact the void.

The test will be accomplished as follows:

Each temperature control will be set to 59°C and it is postulated that within 10 minutes liquid formation will be visible at 0.5 cm from the bottom.

TIME SUMMARY

ITEM	TIME (MINUTES) LIQUID H_2O	LIQUID $C_{18}H_{38}$	SOLID $C_{18}H_{38}$	SOLID $C_{28}H_{58}$
o TEST	96	98	83	109
o HANDLING	13	13	13	13
o EXPERIMENT	109	111	96	122

FIGURE 3-5 EXPERIMENT TIME SUMMARY

ITEM	CLICKS	CAMERA RATE (F/S)	TEMP. SETTING (°C) 1-1	1-2	2-1	2-2	3-1	3-2	TIME (MIN) 1	2	3
INITIAL COOL DOWN	0	SF	0	-12	0	-18	0	-23	10-15	5	5
STABILIZE	1	SF	0	0					10+5		
FUSION FRONT VELOCITY 34.8 X 10^{-3} CM/MIN	2, 3	1/2	0	-13					2.4		
STABILIZE	4	SF	0	0					10+5		
FUSION FRONT VELOCITY 26.7 X 10^{-3} CM/MIN	5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1/2	0	-18					19.8		
STABILIZE	15	SF	0	0					10+5		
MELT FRONT VELOCITY 35.1 X 10^{-3} CM/MIN	14, 13, 12	1/2		9					4.2		
TOTAL									86.4	91.4	96.4

% (WATT)	CELL TRAVEL (IN)	3	2	1
.841	0			
0	.10			
	.20			
.841	.30			
0	.40			
.568	.50			
	.60			
	.70			
	.80			.71
	.90		.76 .71 .66	.66 .61
0	1.00			
.841		.91 .86 .81		

FIGURE 3-6 WATER COOLDOWN

q (WATTS)	CELL TRAVEL (cm)	3	2	1	ITEM	CLICKS	CAMERA RATE (FS)	TEMP SETTING (°C) 1-1	1-2	2-1	2-2	3-1	3-2	TIME (MIN) 1	2	3
.841	0				INITIAL COOL DOWN	0	SF	28	26	28	24	28	22	10-15		
0	.10				STABILIZE	1	SF	28	28					10+5	5	5
					FUSION FRONT VELOCITY 52.8 X 10^{-3} cm/min	2, 3	1/2	28	6					2.4		
.841	.20				STABILIZE	4	SF	28	28					10+5		
0	.30															
328	.40 .50 .60 .70				FUSION FRONT VELOCITY 26.9 X 10^{-3} cm/min	5–14	1/2	28	-6					19.2		
		.80	.74 .79	.70 .75	STABILIZE	15	SF	28	28					10+5		
0 / .841		.85 .70	.64	.60	MELT FRONT VELOCITY 53.3 X 10^{-3} cm/min	14, 13, 12	1/2	28	53					6		
													TOTAL	87.6	92.6	97.6

FIGURE 3-7 OCTADECANE COOLDOWN (LIQUID INITIAL STATE)

q (WATTS)	CELL TRAVEL (IN)	3	2	1	ITEM	CLICKS	CAMERA RATE (F/S)	TEMP SETTING (°C) 1-1	1-2	2-1	2-2	3-1	3-2	TIME (MIN) 1	2	3
0	0					0										
					STABILIZE	1	SF	27	27					10+5		
.841	.10				MELT FRONT VELOCITY 52.8 x 10^{-3} CM/MIN	2, 3	1/2	27	49					2.4		
0	.20				STABILIZE	4	SF	27	27					10+5		
325	.30 .40 .50 .60 .70				MELT FRONT VELOCITY 26.9 x 10^{-3} CM/MIN	5–14	1/2	27	60					19.2		
		.81	.74 .79	.70 .76	STABILIZE	15	SF	27	27	27	22	27	17	10+5		
0 / .841		.86 .71	.64	.61	FUSION FRONT VELOCITY 53.3 x 10^{-3} CM/MIN	14, 13, 12	1/2	27	5					6		
													TOTAL	72.6	77.6	82.6

FIGURE 3-8 OCTADECANE MELT (SOLID INITIAL STATE)

q (WATT)	CELL TRAVEL (cm)	3	2	1	ITEM	CLICKS	CAMERA RATE (F/S)	TEMP. SETTING (°C) 1-1	1-2	2-1	2-2	3-1	3-2	TIME (MIN) 1	2	3
0	0 – .05				STABILIZE	1	SF	59	59					10-15		
.325	.05 – .15				MELT FRONT VELOCITY 24.8 X10^{-3} CM/MIN	2, 3	½	59	79					2.4		
0	.15 – .20				STABILIZE	4	SF	59						10+5		
.651	.20 – .70				MELT FRONT VELOCITY 41.2 X10^{-3} CM/MIN	5 THRU 14	½	79	79					6		
0	.70 – .75				STABILIZE	15	SF	59	59					10+5		
.325	.75 – 1.86				MELT FRONT VELOCITY (OBSERVATION NOT REQ'D)	16 THRU 41		79	79					25.9		
	1.86	.10	.03 – .08	0 – .05	STABILIZE	1	SF	59	59	59	54	59	49	10.5	5	5
0 / .325		.15 – .41	.08 – .33	.05 – .30	FUSION FRONT VELOCITY 25.4 X10^{-3} CM/MIN	2, 3, 4, 5, 6	1/2	59	13					5.4		
													TOTAL	99.7	104.7	109.7

FIGURE 3-9 OCTACOSANE MELT

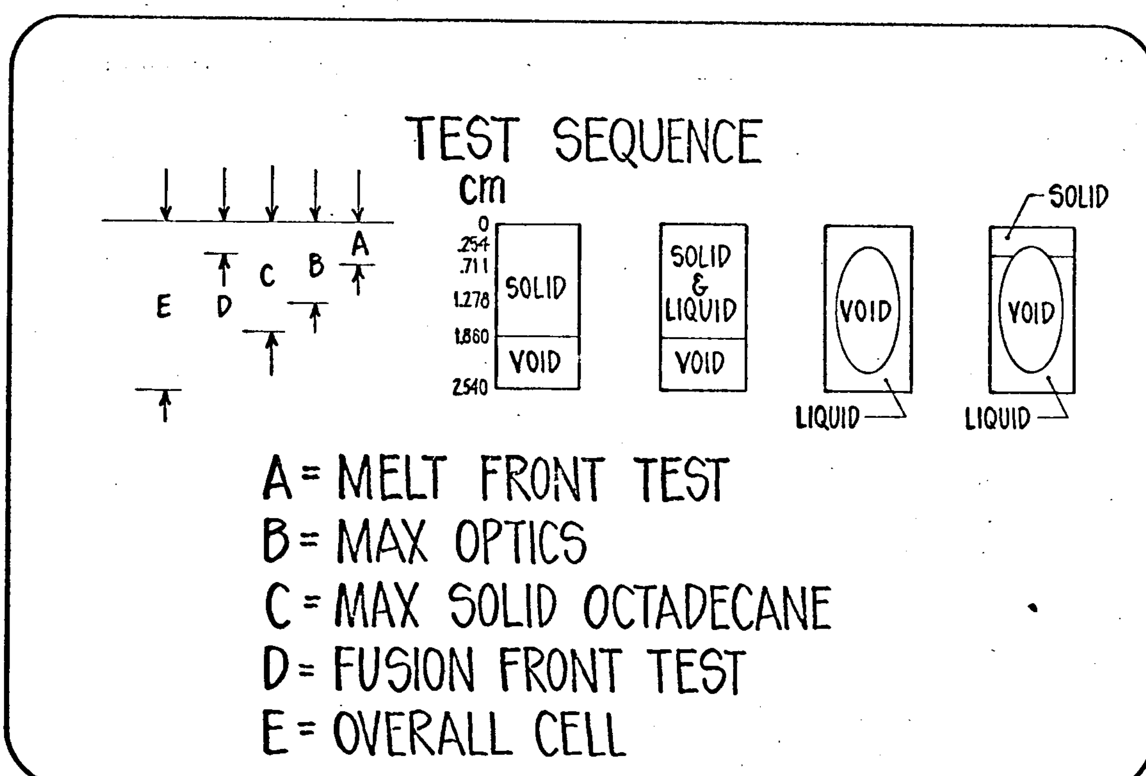


FIGURE 3-10 OCTACOSANE MELT TEST SEQUENCE

Five minutes will then be used to observe the initial melt and to take single frame pictures.

Temperature control settings will then be adjusted to 59°C and 69°C. During the ensuing 2.4 minutes, the interface will progress approximately .10 cm at a melt front velocity of 24.8×10^{-3} cm/min. During this time, motion pictures will be taken at the rate of one frame per 2 seconds. A heat input of .325 watts is required.

The temperature controls will then be set at 59°C and 59°C. During the next 5 minutes, the interface will stabilize at between .15 and .20 cm during which time pictures will be taken on a single frame basis.

The temperature controls will then be set at 59°C and 79°C and in 6 minutes the interface will move from .20 cm to .70 cm at a melt front velocity of 41.2×10^{-3} cm/min. During this time, pictures will be taken at a rate of one frame per 2 seconds. A heat input of .651 watts is required.

The temperature controls will then be set at 59°C and 59°C. During the next 5 minutes, the interface will stabilize at between .70 and .75 cm during which time pictures will be taken at a single frame rate.

The temperature controls will then be set at 79°C and 79°C. During the next 25.9 minutes, the interface will move from .75 cm to 1.86 cm, resulting in a final melt of all the solid octacosane. During this time, any microscope observations or motion picture taking will be as dictated by existing circumstances.

At the conclusion of the melt, the actual position of the void in the liquid octacosane will be studied by moving the test cell, within the 1.27 cm limits of its travel, and making microscope and motion picture observations.

The test cell will then be placed in its zero cm (or initial) position.

The temperature controls will then be set to 59°C and 58°C. If crystallization does appear, it should occur between 0 to 0.5 cm within the next 15 minutes. If it does not occur, the temperature controls will be set to 59°C and 54°C. If crystallization still does not occur within 5 minutes, the temperature control will then be set to 59°C and 49°C for an additional 5 minutes. During each of these periods, microscope observations will be made and pictures will be taken on a single frame basis. It is during this portion of the test that data will be secured on supercooling effects on crystal formation.

The temperature controls will then be set to 59°C and 23°C. During the next 5.4 minutes, the interface will move through the liquid at a fusion front velocity of 25.4×10^{-3} cm/min and intersect the void in the test cell.

3.2.1.2 Radiator Experiments

The space radiators will be located on the mode line of the SM with a two π steradian view of space. The radiators will reject heat to dark space and are designed to operate with full or no solar irradiation. Electrical heaters are mounted on the radiator back side to simulate heat generating equipment. The radiators will be operated at three power levels for four test runs. The first power cycle will be stopped prior to complete liquefaction to facilitate a resolidification cycle with a seeded melt.

The liquefaction period for the PCTR is presented in figure 3-11. The temperature history for the minimum and maximum power cycle is shown in figure 3-12. Note the temperature plateau for solid-to-solid transition and the melt phase due to the properties of the phase change material, octacosane. The resolidification cycle is presented in figure 3-13.

The experiment runs will be initiated by the astronaut with a start button. The astronaut will record start time to correlate the vehicle

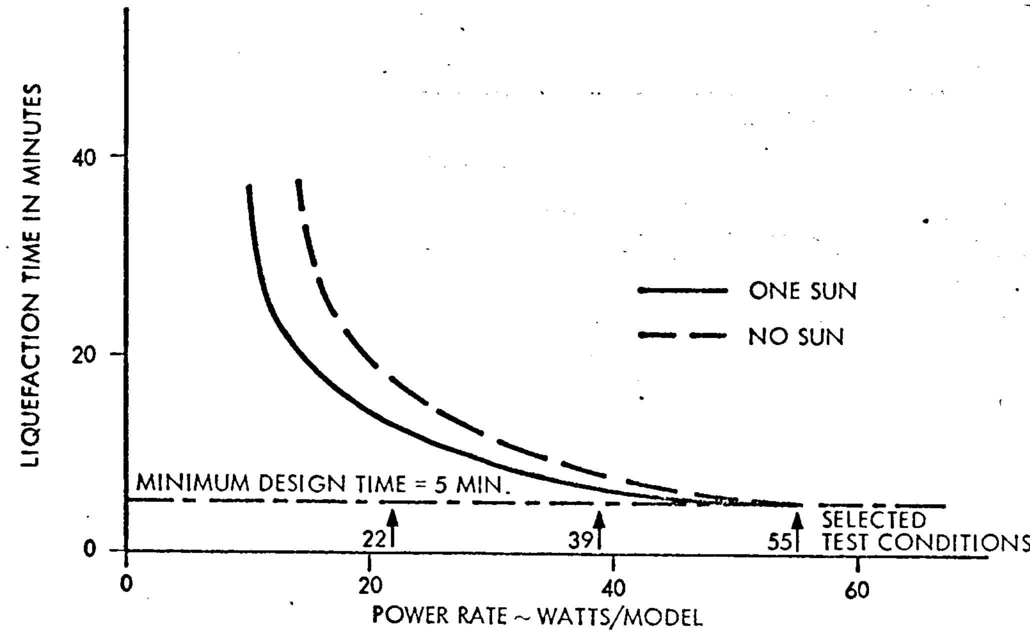


FIGURE 3-11 LIQUEFACTION PERIOD FOR PHASE CHANGE RADIATOR

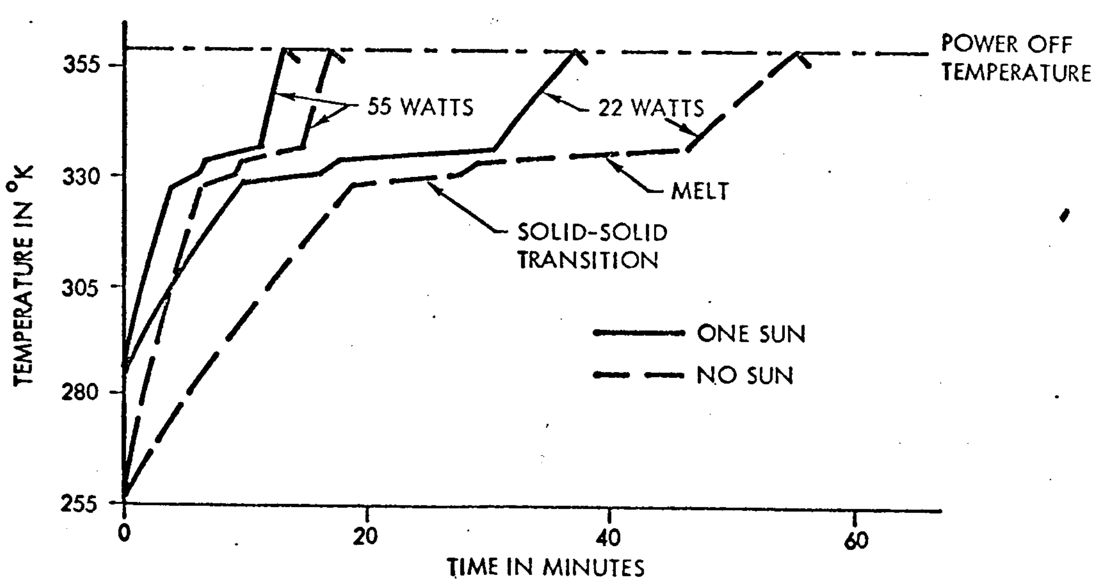


FIGURE 3-12 POWER CYCLE - PHASE CHANGE RADIATOR TEMPERATURE HISTORY

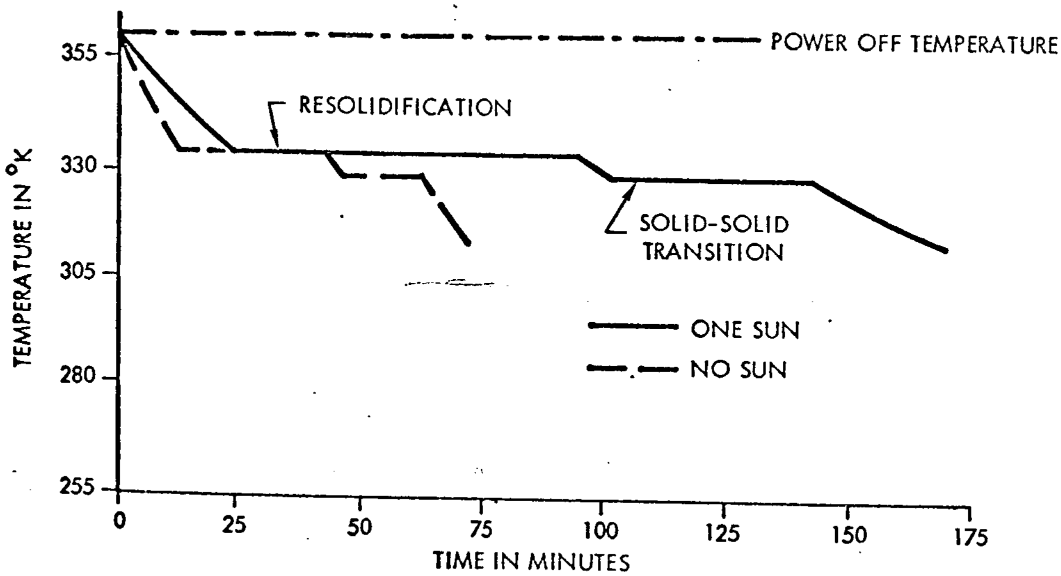


FIGURE 3-13 POWER OFF - PHASE CHANGE RADIATOR TEMPERATURE HISTORY

attitude history. The automatic control system will perform the following control functions:

1) Turn power and data ON.
2) Turn power OFF.
   a) PCTR
      Run 1, 22 watts, incomplete liquefaction
      Power OFF is controlled by a temperature switch and timer
      Control temperature 327 ± .5°K.
      Time 9 minutes ± 1%
      Runs 2, 3, and 4; 22, 39, and 55 watts
      Power OFF is controlled by temperature switch at 358 ± .5°K
   b) Simple Radiator
      Power OFF is controlled by temperature switch at 403 ± .5°K
3) Data OFF (end test run)
   Data recording is terminated by temperature switch at 313 ± .5°K.

The sink radiator is identical in design to the space PCTR. The sink radiator experiment will operate in a controlled environment to isolate the effects of gravity on the PCTR performance. The radiator is thermally isolated by high vacuum and reflective shielding. The heat leak through the mounting structure, four (4) low conductivity metallic U-bolts, will be monitored. The radiator rejects heat to a controlled heat sink which is cooled with liquid nitrogen. The radiation exchange factors, shape factor and surface coatings are controlled and well known so that direct comparison can be made between 1 "g" and zero "g" performance data.

Functionally, the sink radiator can be located in any sector of the Apo vehicle. In the CM, a hard vacuum container would be required for the sink radiator. Locating the sink radiator in the SM deletes the requirement for hard vacuum shell and also deletes the nitrogen storage requirement in the CM. Using this approach, the sink radiator and support systems will be mounted on the space radiator module.

The sink radiator test sequence and operation is identical to the space radiator experiment except for experiment initiation. The cold place is precooled by the nitrogen support system to 100°K prior to starting the first power cycle.

The temperature history for the sink radiator is the same as the space radiator for the no-sun condition, figure 3-12 and figure 3-13. The temperature and power measurement techniques are identical with the space PCTR with the addition of monitoring the cold plate temperature.

3.2.1.3 Support Subsystems

3.2.1.3.1 OBSERVATION UNIT EXPERIMENT -- The observation unit experiment data requirements include temperature measurements, visual observation and filmed data. The following data will be collected and stored during the experiment.

a) Temperature Data
Readings of five thermocouples will be taken on a 4-second basis for a total of 190 minutes. The temperature range is presented in table 3-3.

b) Filmed Data
During the stabilized periods, a camera will be operated on a single frame basis at the discretion of the astronaut, and during the periods of interface movement it will be operated on a one-frame-per-2-seconds basis for a total of 190 minutes.

c) Visual Operation
Microscope observations will be made for a total of 165 minutes.

d) Gravity
Gravity determinations will be secured from the vehicle G&N system.

3.2.1.3.2 RADIATOR EXPERIMENTS -- There are two radiator experiments (space and sink radiator) each containing one phase change thermal radiator (PCTR). The space radiator experiment also includes a simple solid aluminum radiator. Data and power requirements are shown on tables 3-4 and 3-5 for the space radiator and sink radiator sensing units respectively.

TABLE 3-3 RANGE OF TEMPERATURES TO BE MEASURED AT OBSERVATION UNIT AND EQUIVALENT COPPER-CONSTANTAN THERMOCOUPLE OUTPUTS

Experiment	Fusion Temp °C	Temp Extremes °C	Temp Range °C	Thermocouple Output MV*	Range MV*	Remarks
Water (Normal)	0	-18 to 9	27	.182 to 1.210	1.028	
Water (Super-cooled)	-	-23 to 9	32	0 to 1.210	1.210	
Octadecane (Liquid)	28	-5 to 53	58	.699 to 3.024	2.355	
Octadecane (Solid)	28	-5 to 60	65	.699 to 3.327	2.658	
Octacosane (Normal)	59	13 to 94	81	1.368 to 4.858	3.490	
Summary		-18 to 94	112	0 to 4.858	4.858	Sensitivity .0398 MV/°C or .0230 MV/°F

*Referenced to -23° C

TABLE 3-4 SPACE RADIATORS POWER AND DATA SUMMARY

Test Run No.		*1	2	3	4	Total for Four Runs
Nominal Power (Watts)		22	22	39	55	
Maximum Power Cycle (Minutes)	Phase Change	37	55	26	17	135
	Simple	49	49	22	14	134
Maximum Power (Watt Hours)	Phase Change	13.6	20.3	16.9	15.6	66.4
	Simple	18.0	18.0	14.3	12.8	63.1
Maximum Data** Time (Minutes)	Phase Change	173	226	197	188	784
	Simple	133	133	106	98	470

*Run One: Incomplete liquefaction of phase change material

**Data Rate: Record data every 32 sec ± 1%

TABLE 3-5 SINK RADIATOR POWER AND DATA SUMMARY

Test Run No.	*1	2	3	4	Total for Four Runs
Nominal Power (Watts)	22	22	39	55	
Maximum Power Cycle (Minutes)	37	55	26	17	135
Maximum Power (Watt Hours)	13.6	20.3	16.9	15.6	66.4
Maximum Data** Time (Minutes)	84	117	88	79	368

*Run One: In complete liquefaction of phase change material

**Data Rate: Record data every 32 Sec ± 1%

All data is automatically recorded for these units. Ten temperatures are required for the space radiator experiment and seven for the sink radiator. The heater voltage level is recorded for each radiator. The data rate is one complete readout every 32 seconds for the times indicated in the tables.

The PCTR units require two temperature measurements on the radiator surface and two on the heat input side of the phase change package. These measurements will define heat transfer through the phase change package and radiator edge effects. An additional temperature measurement is required on the heater to determine the heat stored therein and the calibrated resistance for the heater elements.

The simple radiator is solid aluminum and only requires two temperature measurements on the radiator and one on the heater . The temperature difference across the mass simulated package (i.e., solid aluminum) is neglectable

All radiators will be mounted on four (4) low conductivity metallic U-bolts. The radiator edge temperature measurement will define one U-bolt end temperature. The temperature on the structure end of one U-bolt will be measured to define the heat leak through this support system. The sink radiator requires a temperature probe on the cold sink for experiment initiation and monitoring the resulting temperature requirements for the radiator experiments are:

Experiment	Radiator	Location	No. Probes	Total Measurements
Space Radiator	PCTR	Heater	1	
		Package (heater face)	2	
		Radiator	2	
		U-Bolt (structure end)	1	6
	Simple	Heater	1	
		Radiator	2	
		U-Bolt (structure end)	1	4

Experiment	Radiator	Location	No. Probes	Total Measurements
Sink Radiator	PCTR	Heater	1	
		Package (heater face)	2	
		Radiator	2	
		U-Bolt (structure end)	1	
		Cold-plate	1	7
		Total temperature measurements		17

In addition, the voltage supplied to the radiators will be monitored to determine power input.

3.2.2 FUNCTIONS AND INTERFACES

Functions and interfaces exist between the phase change thermal radiator flight experiment and the Apollo vehicle and between the major functions of the PCTR flight experiment. These functions and interfaces as defined for the experiment are shown on Phase Change Thermal Radiator Flight Experiment Functions and Interfaces (figure 3-14).

3.2.2.1 Additional Data

Additional data will be required during the experiment operation in the form of mission time. Although PCTR performance can be directly compared to the single calibration radiator performance, sun angles in relation to the radiator surfaces will be required in order to reduce radiator data to a base line level. This radiator surface incident radiation information will be obtained indirectly from the Apollo G&N computer which stores SC inertial attitude during the mission. Therefore, the only data required during experiment operation is the G&N digital time readout which the astronaut will record on his clip board at the start point of the sensing unit operation.

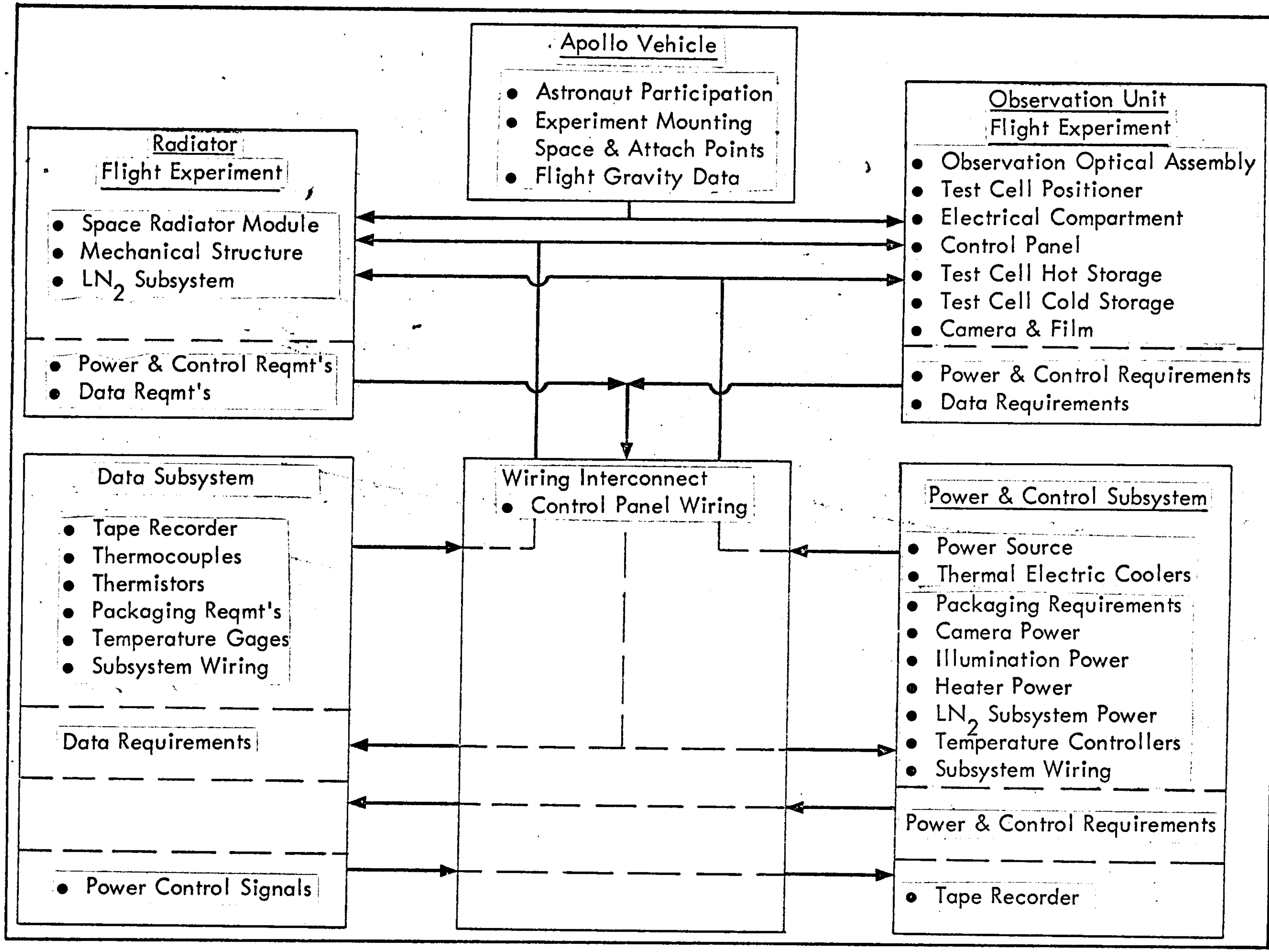


FIGURE 3-14 PHASE CHANGE THERMAL RADIATOR FLIGHT EXPERIMENT FUNCTIONS AND INTERFACES

3.2.2.2 Experiment/Apollo Interfaces

Although the Phase Change Thermal Radiator Flight Experiment shall be designed to be self-sustaining in regard to support functions such as power and data recording, it must be physically mounted in specific areas of both the Command and Service Modules, and use ships cabling for hardwire connections. The experiment must also be placed in operation, monitored and controlled by an astronaut, and at completion of the test runs, an astronaut may retrieve at least one experiment module through an EVA. This section defines these interfaces and the resulting spacecraft modifications necessary to integrate the experiment into the basic Apollo earth orbital mission.

3.2.2.2.1 EXPERIMENT/COMMAND MODULE INTERFACES -- Since the bulk of the experiment equipment is stored and operated inside the Command Module (CM), the major interface in this area is structural and interconnecting to the ships cabling. Figure 3-15 is an interior view of the CM looking directly at the lower equipment bay. Two storage voids shown in figure 3-16 have been assigned to contain the experiment. The term void is used to indicate that experiment equipment housed in these areas must be contained in their own structural boxes complete with tie down provisions (pip pins, etc.) that will interface directly with the surrounding CM structure. The large void, called the "rock box" is 48.3 cm x 20.3 cm x 29.2 cm (19 in. x 8 in. x 11.5 in.) in size, and the smaller void normally used to house a still camera, is 25.4 cm x 21.6 cm x 21.6 cm (10 in. x 8.5 in. x 8.5 in.) in size.

Because one of the experiment modules (space radiator) is located in the Service Module (SM) an electrical interface is required between the experiment power, control and data modules and the CM/SM wire bundle that electrically ties the SM Section I area to the interior of the CM. This wire bundle consists of 44 No. 24 wires, 8 No. 16 wires and two 50-ohm coaxial cables. All of these wires are terminated at each end into standard Cannon plugs. Since not all of these wires will be needed for this experiment, exact Cannon plug connector callouts will not be made at this time.

Several other MC interfaces exist that are of importance to experiment operation. For proper space radiator data reduction, an accurate indication of CM/SM inertial attitude must be known. This data is available as recorded data from the Apollo Guidance and Navigation (G&N) System. However, a time correlation must be maintained between the G&N clock and experiment operation time. This time reference will be maintained by requiring the astronaut to record on his flight kit pad a reference time (visually displayed on G&N panel) at the time each important experiment sequence is started and completed.

Proper observation unit operation is extremely dependent on adequate lighting conditions for both visual and photographic observations. Although the observation unit has its own light source for photography and microscope observation, the CM lighting system will be needed for overall observation unit operation.

Finally, all three experiment sensing units must be operated under as near zero g conditions as possible. The CM/SM attitude control system can supply an attitude-hold dead band about any axis of ±0.5 degree. For the worst case (empty SM propellant tanks), this dead band will result in an attitude rate in the roll axis of 2.4 arc minutes per second. For other axes and with a fully loaded spacecraft, the attitude control rates will be lower.

3.2.2.2.2 EXPERIMENT/SERVICE MODULE INTERFACES -- The basic experiment to SM interface involves the physical mounting of the space radiator module in the skin of Sector I. Figure 3-16 shows the selected location midway between ACS jet modules and on the intersection of 45 degree lines through the jet module axes. This position provides a sheltered location away from ACS jet plumb impingement while still being reasonably close to the CM EVA hatch. The interface itself involves a slightly recessed mounting pad for the space radiator module and a quick disconnect mounting device for the launch cover. In addition, an access door to the space radiator data package is provided in the Sector I skin immediately adjacent to the main cutout. This door will be used during ground checkout only for module adjustment and GSE to module access.

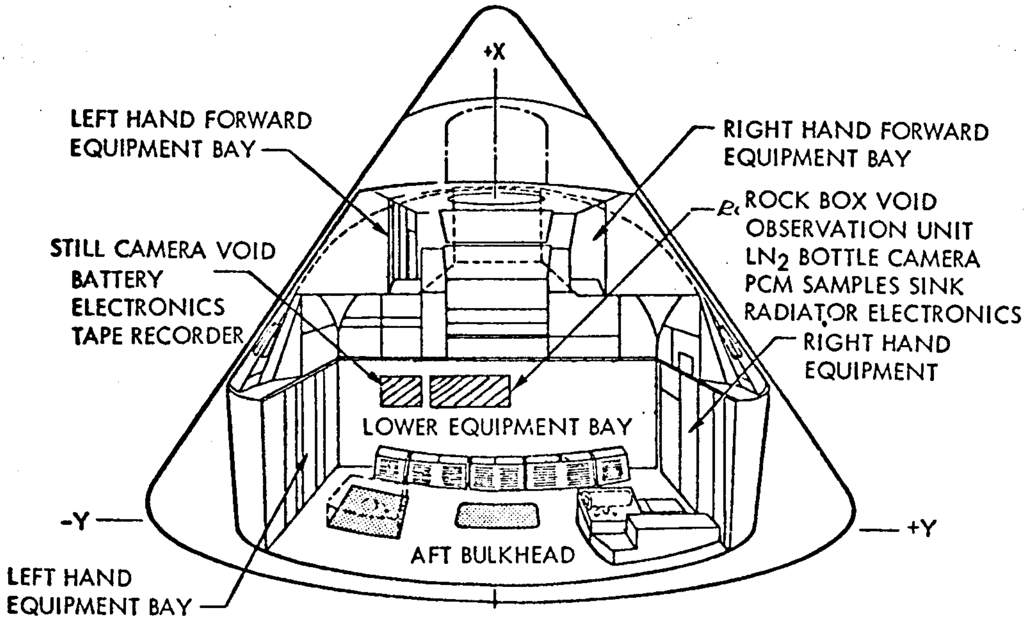


FIGURE 3-15 APOLLO CREW COMPARTMENT,
INT VIEW FROM -Z AXIS

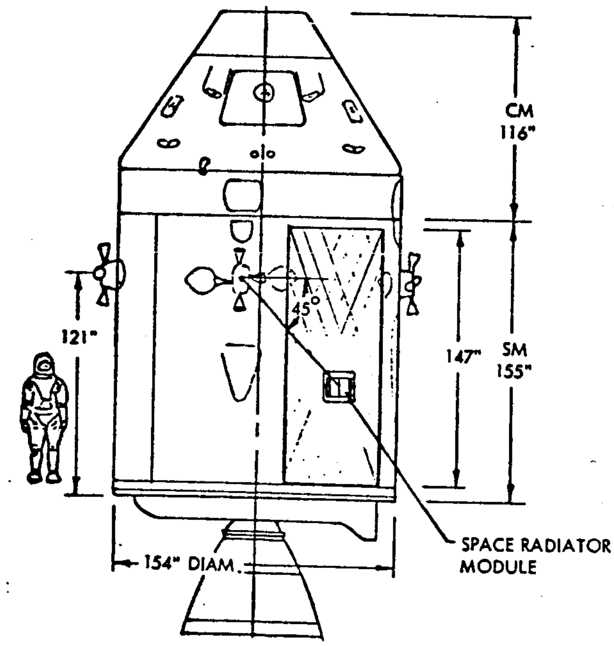


FIGURE 3-16 SPACE RADIATOR LOCATION
IN SERVICE MODULE

An interface also exists between the radiator module data and power package and the SM experiment cable connector. As with the CM cable connector, the exact Cannon connector will not be specified now since other experiments located in the SM Sector I will in all probability be using the same cabling bundle.

3.2.2.2.3 <u>EXPERIMENT/ASTRONAUT INTERFACES</u> -- The Astronauts' interface with the experiment through all phases of its setup, control and operation will be performed inside the CM with the astronaut operator dressed in a constant wear garmet in shirt sleeve conditions. The setup interfaces are as follows:

1) Remove observation module from rock box void.
2) Eject space radiator heat shield and initiate cool down of radiator heat sink.

All of the above operations will be performed using handles, switches, pip pins, connectors, etc., that are standard for manned Apollo operation.

The operational interfaces are for the most part between the astronaut and the observation unit control panel. Figure 3-17 depicts an astronaut seated in his couch in the 212 degree position while observing crystal growth in one of the sample phase change materials. As figure 3-17 shows, he is restrained at the feet and lower trunk positions leaving his hands and head completely free to properly monitor and control the experiment. At various times throughout the operation of the various experiment sensor units, it will be necessary that the astronaut visually note mission time from the G&N board and record this data on a clip board attached to one of his legs.

The interfaces between the astronaut and the space radiator package during retrieval of this module are simple in nature if the actual EVA operation itself is not considered as a part of the experiment. The module to be retrieved will be released by four simple motions (release cam latches) on the part of the astronaut and withdrawn from its cavity using handles

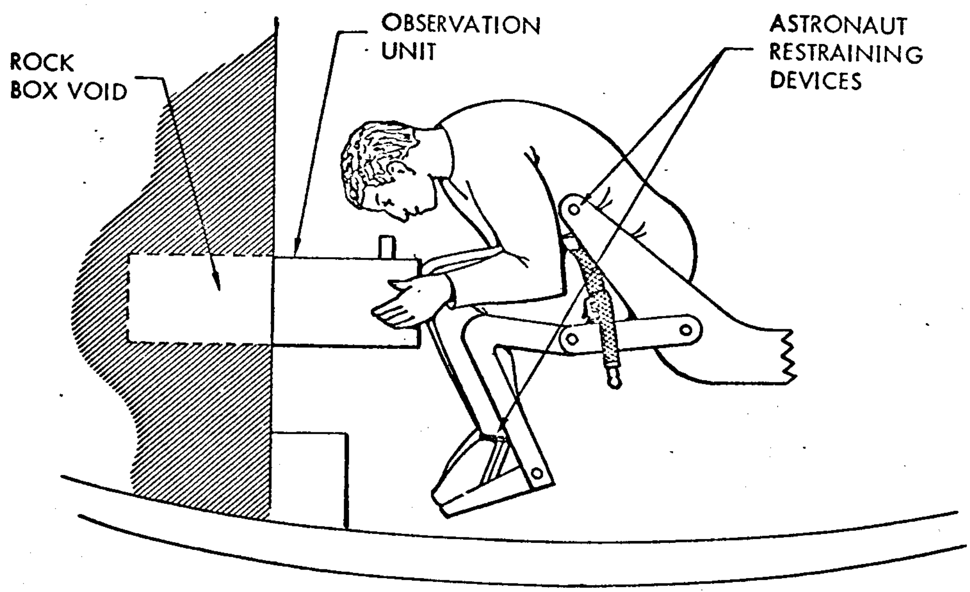


FIGURE 3-17 ASTRONAUT OPERATING OBSERVATION UNIT

specifically designed to accommodate a gloved hand. As the module is removed from the cavity in the SM skin, all electrical connection will also be automatically released. Upon return to the CM, this module will be stored under the couches for the remainder of the mission and the reentry maneuvers.

3.2.2.3 Inner Experiment Interfaces

The Phase Change Thermal Radiator Flight Experiment shall be designed to be self-sustaining in regard to support functions such as data, power and control, liquid nitrogen supply and wiring interconnect. The inner experiment interfaces are established by the following allocations of required hardware: The Observation Unit Flight Experiment shall include an optical assembly, test cell positioner, electrical compartment, test cell hot storage and test cell cold storage.

The Radiator Flight Experiment shall include a space radiator module, mechanical structure and liquid nitrogen subsystem.

A wiring interconnect and control panel interconnect the wiring for the total PCTR flight experiment. The control panel will be comprised of several switches, indicator lamps, and a display meter. These switches will include the following:

1) An off-on toggle switch for system power.

2) A pushbutton type START switch which will initiate the start of an experiment run. This switch has a built-in indicator lamp to indicate that the data system is on.

3) A pushbutton switch, Heater Control Override, which will remove heater power in the event the controller has not switched off heater power after the prescribed temperature of the radiator experiments is attained. This switch also contains a lamp which indicates heater power on.

4) A pushbutton type stop switch used to terminate observation unit runs and to abort any experiment runs, if necessary, for whatever reason. The switch will have a protective guard to prevent inadvertent switching.

5) A three-position rotary switch will select Space PCTR, Sink PCTR, or Observation unit. This switch enables the proper multiplexer and heater control circuits, selects data frame rate, and connects proper signal conditioning amplifiers to display meter.

6) A four-position rotary switch selects the experiment run and the type of material to be studied in the Observation unit. It codes the data so that material and/or test run can be identified.

7) A five-position rotary switch to select the control mode for the observation experiment thermoelectric coolers.

8) A switch to eject the radiator experiment heat shield.

9) A switch to activate the Sink Radiator experiment LN_2 Cooling System.

Also, the panel will contain a record light which blinks on for a period of 375 milliseconds during the record cycle to indicate a data frame.

The data subsystem shall include a tape recorder, thermocouples, thermistors, temperature gages and the required data subsystem wiring.

The power and control subsystem shall include 2 thermal electric coolers, 2 temperature controllers and a power source for the thermal electric coolers, camera, illuminator, heater, tape recorder, liquid nitrogen subsystem and the required power and control subsystem wiring.

3.2.3 CONCEPTS AND APPROACHES

3.2.3.1 Observation Unit

In the development phase, the following major hardware methods were determined:

a) Crystal growth initiation

b) Test cell temperature control

c) Test cell illumination

3.2.3.1.1 CRYSTAL GROWTH INITIATION -- Crystal growth initiation can be accomplished by a seed injection device and/or by temperature control of the interface between a solid and its melt.

In the seed injection method, a seed injector would inject a seed with a low velocity into a supercooled liquid. The position at which the seed would be injected into the supercooled liquid would greatly influence the position of the resultant crystal growth. Ideally, the seed should be placed at the top of the camera field of view in the center of the tube so that a uniform crystallization front would move through the camera frame. Consequently, it would be necessary to design a seed positioner which accurately controls the placement. The seed injector and positioner should be reusable for each experiment.

L. J. Thomas and J. W. Westwater studied solid-liquid interfaces during melting and freezing using a rectangular parallel-piped test sample with contact heating and cooling at two opposite end planes. By varying the end plane, temperature solidification (and/or supercooling) and liquefaction can be induced in the test material. The velocity of the fusion or liquefaction front can also be unidirectionally controlled. This technique reduces total experiment time through the use of conduction heating and cooling. Increased control of observation time is obtained because the fusion or liquefaction front can be held constant or moved at controlled velocities.

For reasons of design simplicity and required experiment time, the basic features of the Thomas/Westwater technique have been incorporated into the design of the observation unit.

3.2.3.1.2 TEST CELL TEMPERATURE CONTROL -- Crystal growth temperature control can be accomplished by either thermal-radiation or conduction methods.

The thermal radiation method necessitates large temperature differences. With the melt temperature of the test materials and the mission restraints on experiment time, the radiation control requires cryogenic sink temperatures for solidification and source temperatures in the order of 150°C for liquefaction. The conduction method requires sink and source temperatures of approximately -10°C to 95°C.

A conduction method utilizing thermo-electric cooling modules was selected for the observation unit experiment. The selection criteria are:

a) This design approach deletes the liquid nitrogen storage requirement in the CM. Removal of the LN_2 subsystem from the CM deletes the potential cryogenic storage problem in a spacecraft shirt sleeve environment. Also, the requirement to connect the exhaust line to a CM overboard dump is deleted.

b) The preliminary packaging design study, Phase I, showed that additional experiment storage volume would be required in the CM for the experiment hardware and sufficient LN_2 (+ tankage) for both the observation and sink radiator sensing units.

c) The thermal electric cooling system, including heat sinks and power supply, required less weight, volume and power than the LN_2 cooling system for the observation unit.

d) The sink radiator and LN_2 support system weight, voluum and functional requirements are compatible with the space radiator module installation.

3.2.3.1.3 TEST CELL ILLUMINATION -- The illuminator selected during the development phase utilizes a point source and beam. The beam is found approximately half way between the cell and the microscope objective lens on the optical center line utilizing the shadograph technique.

3.2.3.2 Radiator Experiments

In the experiment development phase, the following major hardware methods were determined:

a) Core Design
b) Package Design
c) Fill and vent port design
d) Radiator Support
e) Power selection method

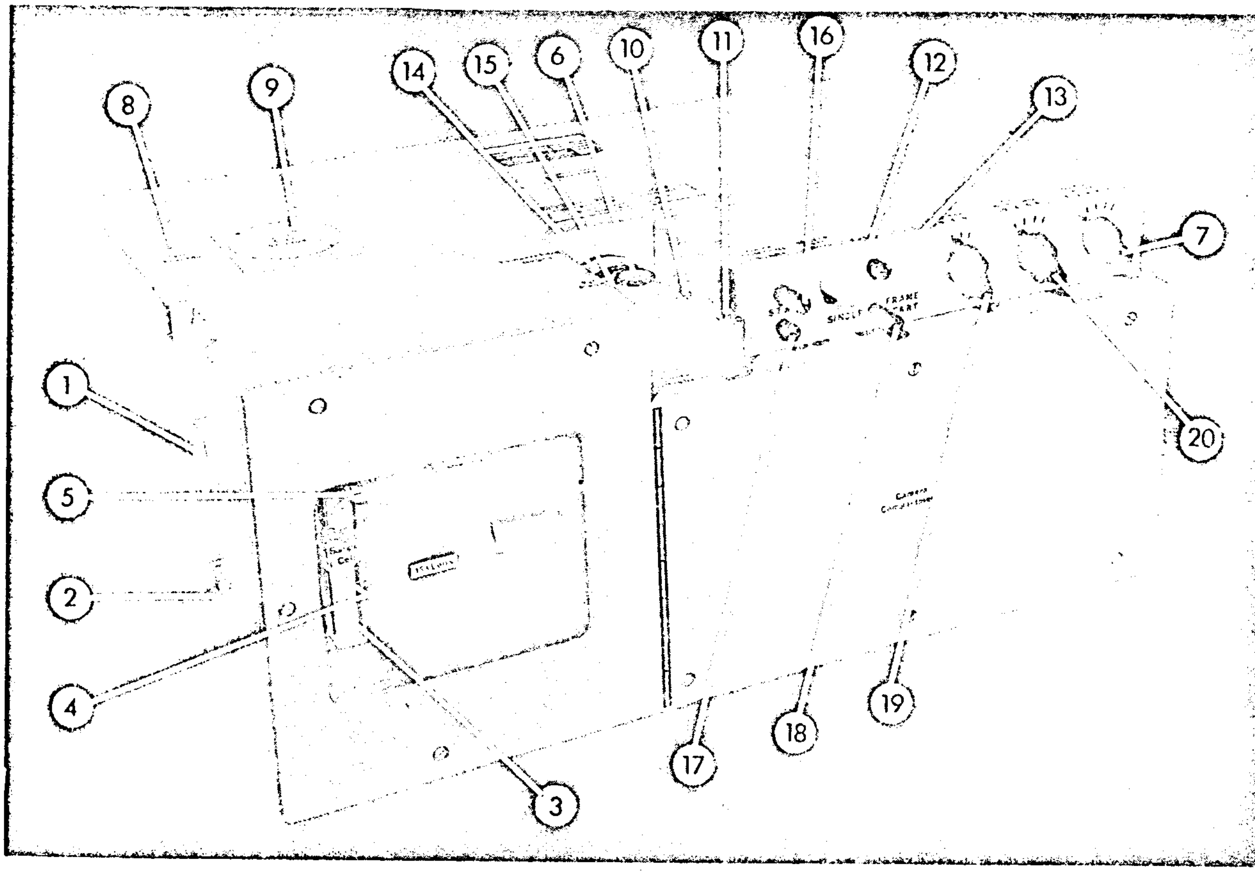
3.2.4 HARDWARE DESCRIPTION

Figure 18 depicts the experiment (radiator(s) and observation) controls located on the Observation Experiment Module. This module is located in the Rock Box Void in the Appollo CM. The controls shown are similar to those incorporated in the Phase II model.

Several on/off switches required for the flight model but not for the development model are not shown on the mock-up. In addition several manual switching functions incorporated in the development model could be automated on the flight experiment. These variances are noted in Figure 3-18.

The power supply module located in the Apollo CM Still Camera Void is automatically controlled by the experiment controls depicted on Figure 3-18.

Figure 3-19 depicts the functional elements of the radiator experiments located in the Apollo SM. The protective heat shield required for launch is not shown. The experiment is connected by hard line to the control panel and power supply located in the Apollo CM. Note that the Radiator module containing the radiator experiments (Space and Sink) and the data package can be retrieved by the EVA for post-flight evaluation.



CONTROLS 1 THRU 11 FOR OBSERVATION (OBSV) EXPERIMENT ONLY

1. CELL POSITIONER ---------- POSITIONS TEST CELL
2. CELL FOCUS ---------- FOCUSES TEST CELL
3. SAMPLE CELL ---------- CONTAINS TEST MATERIAL
4. THERMOCOUPLE BANK CONTROL KNOB --- POSITIONS THERMOCOUPLES ON TEST CELL
5. TEST CELL LOCK ---------- LOCKS CELL IN TEST POSITION
6. EYE PIECE ---------- MICROSCOPE EYE PIECE
7. OBSV CONTROL ---------- ENCODES DATA TAPE AND SELECTS TEST CELL END THERMAL ELECTRIC COOLER/HEATER:
   - 1 = POWER OFF
   - 2-5 = POWER ON, FUNCTIONS COULD BE CONTROLLED AUTOMATICALLY ON FLIGHT EXP
   - 2 = BOTH ENDS IN COOLING MODE
   - 3 = TOP END IN HEATING MODE, BOTTOM END IN COOLING MODE
   - 4 = TOP END IN COOLING MODE, BOTTOM END IN HEATING MODE
   - 5 = BOTH ENDS IN HEATING MODE
8. CELL STORAGE ---------- TEST CELL STORAGE (6 CELLS)
9. CELL COLD STORAGE ---------- TEST CELL STORAGE TO MAINTAIN 2 CELLS IN SOLID STATE (WATER AND/OR OCTADECANE)
10. TEMP CONTROLLER NO. 1 ---------- SETS TEST CELL UPPER END TEMP
11. TEMP CONTROLLER NO. 2 ---------- SETS TEST CELL LOWER END TEMP

CONTROLS 12 THRU 14 FOR RADIATOR (RAD) EXPERIMENTS ONLY

12. HEATER OVER RIDE ---------- BACK UP TO AUTOMATIC HEATER POWER SHUT OFF
13. CALIB ---------- CALIBRATES READING, TEMP GAGE AND DATA TAPE FOR THERMISTORS
14. TEMPERATURE GAGE NO. 1:
   - 14.1 OBSERVATION EXPERIMENT ---------- INDICATES SAMPLE CELL UPPER END TEMP
   - 14.2 RADIATOR EXPERIMENTS ---------- INDICATES PHASE CHANGE RADIATOR TEMPS (SPACE OR SINK)

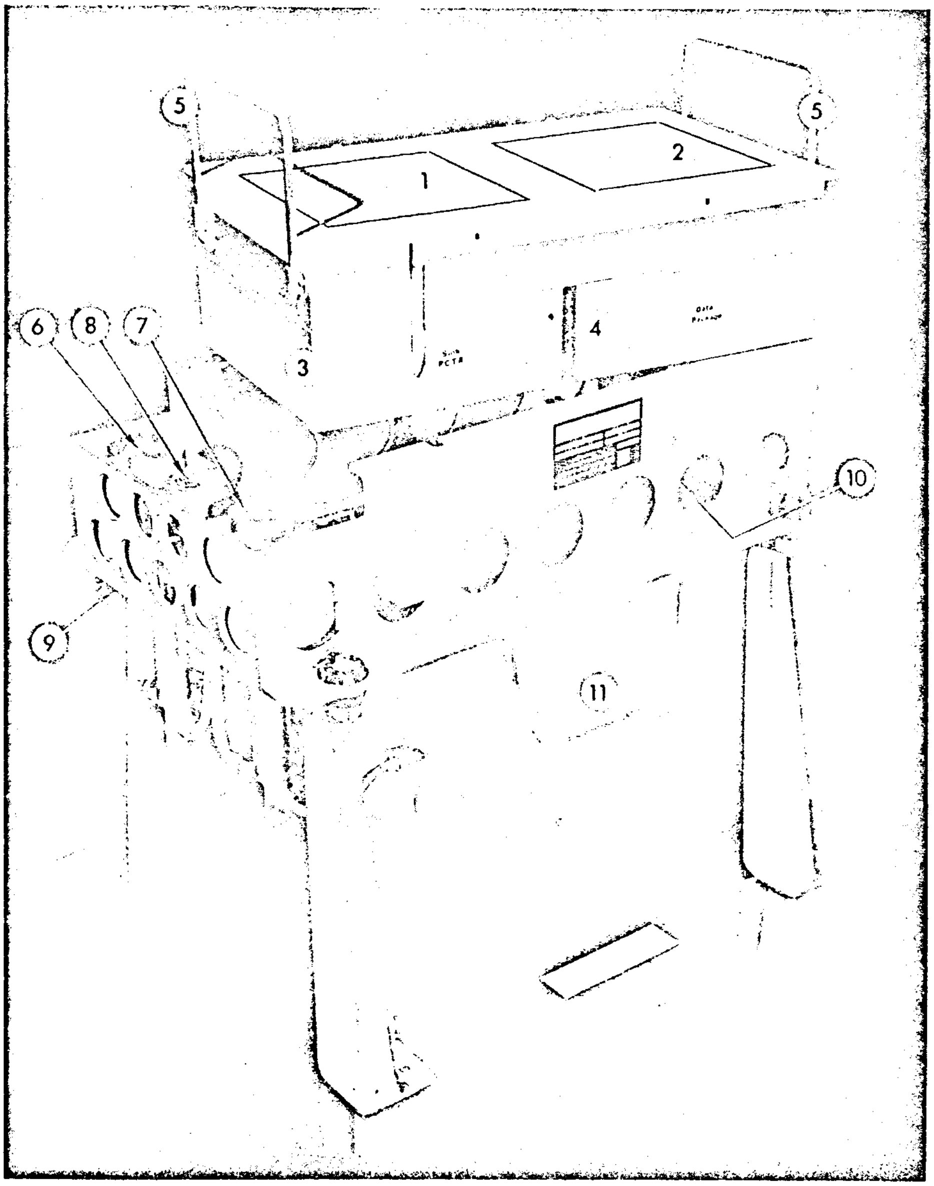
CONTROLS 15 THRU 22 FOR RADIATOR AND OBSERVATION EXPERIMENTS

15. TEMPERATURE GAGE NO. 2:
   - 15.1 OBSERVATION EXPERIMENT ---------- INDICATES SAMPLE CELL LOWER END TEMP
   - 15.2 SPACE RADIATOR EXPERIMENT ---------- INDICATES SIMPLE RADIATOR TEMP
   - 15.3 SINK RADIATOR EXPERIMENT ---------- INDICATES LN_2 COLD WALL TEMP
16. DATA CONTROL START:
   - 16.1 OBSERVATION EXPERIMENT ---------- STARTS DATA AND CAMERA SYSTEMS
   - 16.2 RADIATOR EXPERIMENTS ---------- STARTS DATA SYSTEM AND HEATER POWER
17. DATA CONTROL STOP:
   - 17.1 OBSERVATION EXPERIMENT ---------- STOPS DATA AND CAMERA SYSTEM
   - 17.2 RADIATOR EXPERIMENTS ---------- MANUAL STOP DATA SYSTEM AND HEATER POWER (RAD EXPS HAVE AUTOMATIC SHUT-OFF CONTROLS)
18. SINGLE FRAME START:
   - 18.1 OBSERVATION EXPERIMENT ---------- SINGLE FRAME START, DATA AND CAMERA SYSTEMS
   - 18.2 RADIATOR EXPERIMENT ---------- SINGLE FRAME START, DATA SYSTEM
19. EXP SEL ---------- ENCODES EXPERIMENT ON DATA TAPE AND SELECTS EXP CONTROLS:
   - 1 = SPACE RADIATOR EXP
   - 2 = SINK RADIATOR EXP (ACTIVATES LN_2 SYSTEM AT FIRST DATA CONTROL START)
   - 3 = OBSV EXP (SWITCHES POWER TO CELL ILLUMINATOR, OBSV CONTROL AND TEST CELL THERMOCOUPLES)
20. EXP RUN NO.:
   - 20.1 OBSERVATION EXPERIMENT ---------- ENCODES DATA:
     - 1 = WATER IN LIQUID INITIAL STATE
     - 2 = OCTADECANE IN LIQUID INITIAL STATE
     - 3 = OCTADECANE IN SOLID INITIAL STATE
     - 4 = OCTACOSANE IN SOLID INITIAL STATE
   - 20.2 RADIATOR EXPERIMENTS ---------- ENCODES DATA TAPE AND SELECTS TEST CONDITION:
     - 1 = 22 WATTS AND INCOMPLETE LIQUEFACTION
     - 2 = 22 WATTS AND COMPLETE LIQUEFACTION
     - 3 = 39 WATTS AND COMPLETE LIQUEFACTION
     - 4 = 55 WATTS AND COMPLETE LIQUEFACTION

FLIGHT EXPERIMENT CONTROLS NOT SHOWN ON MOCK-UP

21. MASTER POWER SWITCH ---------- NOT SHOWN ON DEVELOPMENT MODEL, SUBSTITUTED BY POWER SUPPLY SWITCH
22. HEAT SHIELD EJECTION SQUIBS SWITCH --- BLOWS OFF HEAT SHIELD PRIOR TO RAD EXP
23. LN_2 SUPPLY LINE CUTTER SQUIB SWITCH --- FIRE TUBE CUTTER SQUIB FOR EVA RETRIEVAL OF RAD EXP MODULE

FIGURE 3-18 PHASE CHANGE THERMAL RADIATOR FLIGHT EXPERIMENT CONTROLS



1. SPACE PHASE CHANGE RADIATOR
2. SPACE SIMPLE RADIATOR
3. SINK PHASE CHANGE RADIATOR
4. RADIATOR EXPERIMENT DATA PACKAGE
5. RADIATOR EXPERIMENT MODULE EVA RETRIEVAL HANDLES
6. LN_2 FILL VALVE
7. LN_2 FLOW & VENT VALVE
8. LN_2 FILL PORT
9. LN_2 SUPPLY LINE CUTTER
10. ELECTRICAL DISCONNECT
11. LN_2 STORAGE TANK
12. RADIATOR EXPERIMENT LAUNCH HEAT SHIELD NOT SHOWN

FIGURE 3-19 RADIATOR EXPERIMENT MODULE WITH FLIGHT TYPE LN_2 SYSTEM AND SUPPORT STRUCTURE

3.2.4.1 Observation Unit

The optics system schematic, Figure 3-20, presents features of the test apparatus. The water and octadecane samples are contained in variable volume (temperature compensating) test cells. The octacosane test cell has a volume void in the material. Heat is conducted upward or downward through a 2.54 cm depth of test material in a .952 x 1.27 cm cell. The four vertical walls of the test cell are .317 cm Plexiglass 55 conforming to MIL-P-8184.

The horizontal top and bottom plates of the test cell are the heat source and sink.

It is desirable that heat transfer in the cell be unidirectional, therefore, heat exchange with ambient surroundings is minimized.

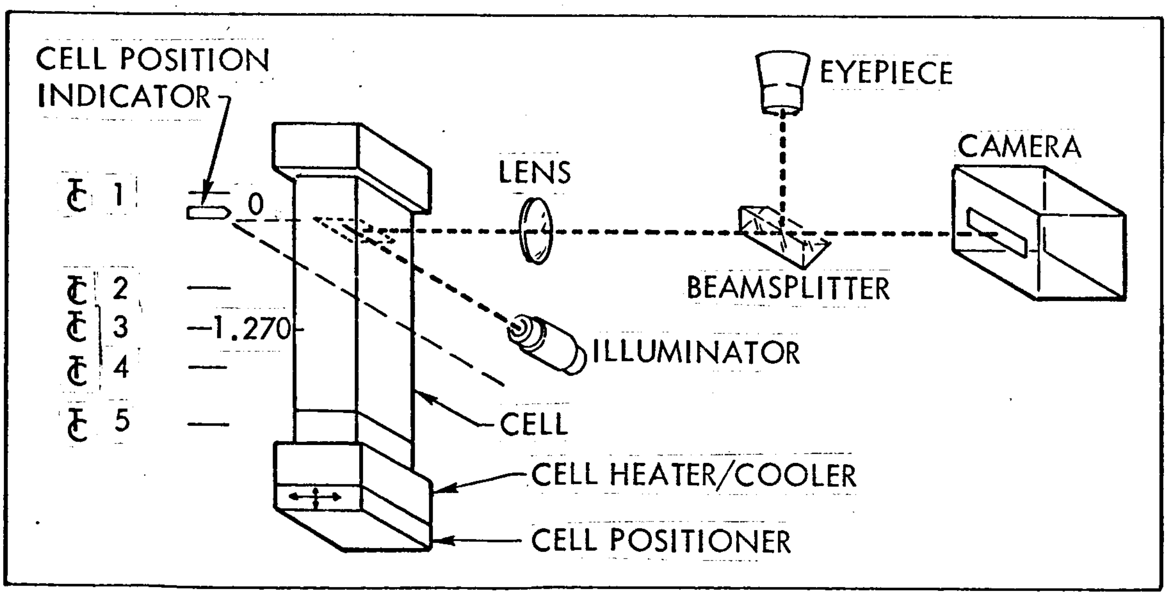


FIGURE 3-20 OPTICS SYSTEM SCHEMATICS

3.2.4.2 Radiator Experiments

The space radiator experiment module consists of: a space radiator, a simple radiator, a data subsystem package and support structure. The module is located on the external mold line of the service module with the radiator surfaces exposed to a 2π steradian view of space. The objective of the Space Phase Change Thermal Radiator Experiment is to verify by test in an actual zero "g" space environment the phase change material concept. The two radiators will provide a direct performance comparison between a Phase Change Thermal Radiator (PCTR) and a simple radiator.

The PCTR incorporates a phase change material to increase thermal inertia and an aluminum honeycomb core for effective heat transfer. The phase change material and honeycomb core are sealed in an aluminum package.

The simple radiator is identical to the PCTR in weight and area, but not in thickness. Both radiators will have the same surface coating, S-13G, and method of support to the frame. The radiators will experience the same space exposure and, thereby, undergo an identical surface coating degradation and realize a similar increase in solar absorptivity. They will be thermally isolated from internal heat sources by means of aluminized mylar blankets. Four low conductivity metallic U-bolts will support each radiator. The supporting frame is made from low thermally conductive materials to minimize heat exchange between the radiators and the service module structure. Two heater elements on the back side of each radiator will provide a controlled heat input to the radiator package. These heaters will be operated separately and in series to provide three power levels.

The PCTR radiator aluminum honeycomb core was designed to provide effective heat transfer to the radiator surface and the phase change material. The core design parameters are:

Material:	3003 aluminum
Cell size:	.95 cm nominal (3/8 inch)
Sheet thickness:	.0030 cm (.0012 inch)
Max sheet spacing:	.060 cm (.0236 inch)
Package thickness:	1.27 cm (.5 inch)

This core design results in 10% of the package void being filled with aluminum honeycomb.

The sink radiator is identical to the space radiator PCTR. The sink radiator is cooled by a LN_2 cooled cold plate.

3.2.4.2.1 LIQUID NITROGEN SUBSYSTEM -- The Liquid Nitrogen Subsystem will be mounted to a subframe which in turn will be mounted to the radiator experiment structure.

The Liquid Nitrogen Subsystem will be subjected to the following storage conditions prior to use:

Ground storage prior to launch - 24 hours
Orbit time prior to usage - 3 days

The Liquid Nitrogen Subsystem will consist of:

A liquid nitrogen storage tank.
A control subsystem.
A plumbing subsystem.

- Liquid Nitrogen Storage Tank - The basic tank design will conform to applicable safety codes for pressure vessels. It will contain a means for positive explusion of the liquid nitrogen.

  Its capacity will provide for:

  a) Preusage storage boil-off.
  b) Usage flow rate of approximately 0.25 lb/hr for 8 hours.

  The back pressure is that established by approximately 2 feet of 1/8-inch OD tubing connecting to approximately 28 inches of 1/16-inch ID tubing, which discharges to a vacuum of less than 10^{-5} mm Hg. Supply line from LN_2 system to experiment will be furnished by Northrop.

- Control Subsystem - The control subsystem will be capable of "on-off" type operation during checkout and "on" type only during the experiment mode. The activating signal shall be 28 volts dc.

- Plumbing Subsystem - The Plumbing Subsystem will, as a minimum, incorporate: an inlet valve permitting ready filling and capping with the system installed in the SM and the spacecraft on the launch pad; an overpressure relief valve and a blowout plug to prevent excessive high pressure conditions; and an electrically activated outlet valve.

3.2.4.3 Support Subsystems

3.2.4.3.1 DATA SUBSYSTEMS -- The data subsystem designed for the PCTR experiment is essentially a low data rate PCM system which is recorded on magnetic tape in serial form. The basic characteristics are:

Bit rate -------------	512 pps
Word rate ------------	64 pps
Word Length ----------	8 bits
Frame Length ----------	16 words

The system has two frame rates: 1.88 frames per minute during the PCTR experiment, and 15 frames per minute during the visual experiments. The data format is shown in figure 3-21. The electronics are located in 4 separate packages:

1. Programmer, which includes system clock, A-D converter, multiplexer control, record control, time code generator and shift register.
2. Radiator experiment (Space & Sink) multiplexer, signal conditioner amplifiers and heater control.
3. Observation unit multiplexer and signal conditioning amplifiers.
4. Tape recorder head selector switch and forward-reverse tape controls.

In general, each unit is constructed using cord wood type welded modules. The potted module size is a one-inch cube with solder terminals on one surface and 4-40 inserts molded into the opposite surface for securing to chassis.

There will be sufficient test points to check out the operation of the digital sections of the data system using a two-channel oscilloscope. A high impedance VTVM will be required to check out the operation of the analog electronics using the VTVM to monitor the input to the A-D converter and a multiplexer control switch which will be supplied to replace the active multiplexer control. This will allow each channel to be observed separately. The linearity and stability of the thermistor signal conditioning amplifiers

WORD	BIT LOCATION IN FRAME	BIT LOCATION IN WORD	OBSERVATION EXPERIMENT	RADIATOR EXPERIMENTS (SPACE AND SINK)	
			IDENTIFICATION	IDENTIFICATION	
1	1-8	1 THRU 8	SYNC 1 (BINARY 11100010)	SYNC 1 (BINARY 11100010)	
2	9-16	1 THRU 8	SYNC 2 (BINARY 11100010)	SYNC 2 (BINARY 11100010)	
3	17	1	EXP SEL = 3, BINARY BIT = 1 (DATA FRAME RATE: TEMP = 15 FPM & CAMERA = 30 FPM)	EXP SEL = 1 OR 2, BINARY BIT = 0 (DATA FRAME RATE 2 FPM)	
	* 18	2	UNASSIGNED	EXP SEL = 1, BINARY BIT = 1, SPACE RADIATOR EXPERIMENT, EXP SEL = 2, BINARY BIT = 0, SINK RADIATOR EXPERIMENT,	
	19	3	TAPE & FILM CORRELATION MARK EVERY 16TH DATA FRAME	AUTOMATIC CALIBRATE EVERY 16TH FRAME (1 = YES) (0 = NO)	
	20	4	UNASSIGNED	MANUAL CALIBRATE (1 = YES) (0 = NO)	
	21	5			
	22	6			
	23	7		UNASSIGNED	
	24	8		UNASSIGNED	
4	25-32	1 THRU 8	TIME CODE, DATA FRAME COUNT FROM START OF RUN.	TIME CODE, DATA FRAME COUNT FROM START OF RUN.	
			DATA	DATA	
				SPACE RADIATOR EXPERIMENT	SINK RADIATOR EXPERIMENT
5*	33-40	1 THRU 8	THERMOCOUPLE A (TEMP. GAGE 1, GREEN)	PCTR THERMISTOR A (TEMP. GAGE 1, GREEN)	PCTR THERMISTOR A (TEMP. GAGE 1, GREEN)
6*	41-48	1 THRU 8	THERMOCOUPLE B	PCTR THERMISTOR B	PCTR THERMISTOR B
7*	49-56	1 THRU 8	THERMOCOUPLE C	PCTR THERMISTOR C	PCTR THERMISTOR C
8*	57-64	1 THRU 8	THERMOCOUPLE D	PCTR THERMISTOR D	PCTR THERMISTOR D
9*	65-72	1 THRU 8	THERMOCOUPLE E (TEMP. GAGE 2, RED)	PCTR THERMISTOR F	PCTR THERMISTOR F
10*	73-80	1 THRU 8	+12 VOLT MONITOR	PCTR THERMISTOR E	PCTR THERMISTOR E
11*	81-88	1 THRU 8	-12 VOLT MONITOR	SIMPLE RADIATOR THERMISTOR F	UNASSIGNED
12*	89-96	1 THRU 8	UNASSIGNED	SIMPLE RADIATOR THERMISTOR D	UNASSIGNED
13*	97-104	1 THRU 8	NOT USED	SIMPLE RADIATOR THERMISTOR E	UNASSIGNED
14*	105-112	1 THRU 8	NOT USED	SIMPLE RADIATOR THERMISTOR B (TEMP. GAGE 2, RED)	COLD PLATE THERMISTOR (TEMP. GAGE 2, RED)
15*	113-120	1 THRU 8	NOT USED	PCTR VOLTAGE	PCTR VOLTAGE
16*	121-128	1 THRU 8	NOT USED	SIMPLE RADIATOR VOLTAGE	UNASSIGNED
16	128	TOTALS PER FRAME			

Observation experiment (bits 21-24):

	WATER	LIQ. OCTADECANE	SOLID OCTADECANE	OCTACOSANE
EXP RUN NO:	1	2	3	4
FORMAT	0	0	1	1
	0	1	0	1

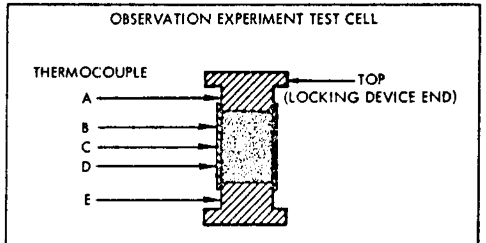
	POWER OFF	THERMAL-ELECTRIC DIRECTION SELECTION			
OBSV CONTROL:	1	2	3	4	5
FORMAT	1	0	0	1	1
	1	0	1	0	1

Radiator experiments (bits 21-22):

	INCOMP. LIQ. 22 WATTS	COMP. LIQ. 22 WATTS	COMP. LIQ. 39 WATTS	COMP. LIQ 55 WATTS
EXP RUN NO:	1	2	3	4
FORMAT	0	0	1	1
	0	1	0	1

KEY:
* = DATA WORD FORMAT: BINARY 0 TO 2^8-1 DECIMAL 0 TO 255

OBSERVATION EXPERIMENT TEST CELL



RADIATOR EXPERIMENT

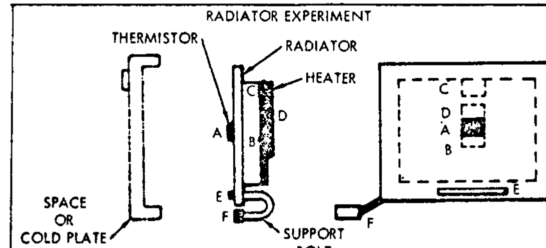


FIGURE 3-21 DATA MEASUREMENTS AND FRAME FORMAT

and heater control circuits can be checked out by substituting a precision decade resistor box for the calibrated thermistor. The thermocouple amplifiers will be checked out using temperature baths to stimulate the thermocouples.

For a complete system checkout, the tape recorder will be played back through the ground support equipment and the digital data will be recorded in parallel form with a recording oscillograph. The data can then be visually analyzed and compared with the test inputs.

Little or no servicing of the data subsystem is expected. There is no requirement for the tape recorder to be opened and the design tape speed of 3.75 ips and packing density of 137 bits per inch will allow the tape recorder to operate many hours with negligible bit drop-out.

3.2.4.3.2 POWER AND CONTROL SUBSYSTEMS -- Power for the PCTR experiment will be obtained from two primary silver-zinc batteries. Preliminary investigations indicate that a +28 volt battery load will be less than 1200 watts and the -15 volt battery energy about 15[illegible] watt-hours. The +28 volt battery serves as the power source for the observation unit temperature control devices, the camera and light source, relays, the radiator experiment heaters, the tape recorder, and the positive regulated voltages. The 15-volt battery is used for the negative regulated voltages. The regulated power requirements are as follows:

+24.0 ± 1.2 vdc at .15 amp
+12.00 ± .24 vdc at .2 amp
+10.000 ± .025 vdc at 0 to 25 milliamp
+4.50 ± .09 vdc at .7 amp
-12.00 ± .24 vdc at .25 amp
-6.00 ± .06 vdc at .2 amp

The 4.50 ± .09 vdc supply will be a switching mode type regulator in order to reduce the losses from the large current and big change in voltage.

The +10.000 ± .025 vdc is used for reference purposes and has to absorb current from the circuits which are clamped by it. It will be controlled by a temperature coefficient zener diode circuit.

The rest of the voltages will be obtained by series regulation since they require less of a voltage drop at relatively small current.

A summary of the total power requirements is shown in Table 3-6. The 1200 watt-hour battery allows approximately 500 watt hours for the cold storage control of the observation experiment cells. A tentative layout for the power supply is shown in figure 3-22.

There will be two identical temperature controllers, one for each end of the sample. The cooling and heating will be accomplished by EG&G Inc.'s thermo-electric module-model G9-65. A separate heat sink will be provided for the hot junction at each end which should keep the temperature below 43°C. At the maximum 9 amp current the Model G9-65 will remove 1/2 watt from the sample at -23°C to the 43° sink. The electronics will be designed to be capable of removing the maximum wattage although this might be required only for the maximum super-cooling of the water test sample.

In order to control the 9 amps maximum the output of the controller is a variable width pulse at a frequency of approximately 7000 pulses per second. The full battery voltage is applied to an inductor in series with the output during the on pulse width. During the off portion the energy stored in the inductor maintains the load current through a diode path from ground. Two 580 uf capacitors in parallel smooth the output. Using this method the only losses in the power output circuit occur in the saturated transistor, the inductor resistance and iron, and the diode drop during the off portion of the cycle.

The controller output can handle current in one direction at a time depending on the selector switch position. The thermo analysis indicated this is the actual case; however, should current be required in either direction because of the ambient conditions, a small current in the heating direction will be supplied from the negative battery (-14v). The small current thus supplied will cause a bias in the controller circuit during cooling but will not present an additional load to the thermoelectric device.

TABLE 3-6 POWER SUMMARY

Experiments and Systems	Watt - Hrs
Temperature Control Observation Unit	84.0
Radiator Units	196.0
Camera and Lamp	240.0
Electronics (Less Controller and Tape Recorder)	150.0
Tape Recorder	2.0
Total at Battery	672.0

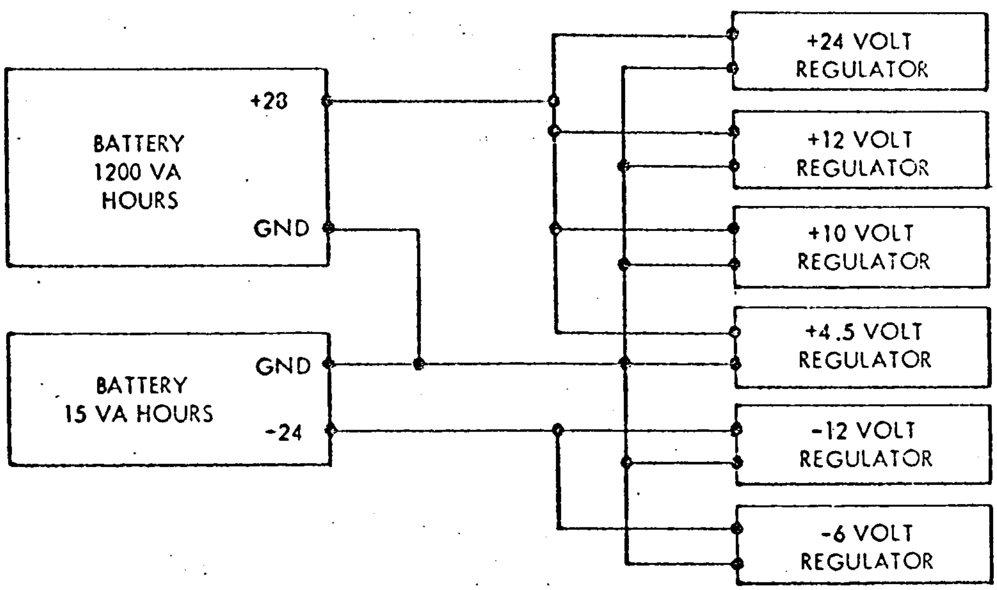


FIGURE 3-22 POWER SUBSYSTEM

A block diagram of the control system for one end of the sample is shown in figure 3-23. Basically it consists of an error detection circuit which compares the sensor output with the desired setting and amplifies the difference.

The error signal is then run through an operational amplifier which can provide the shaping networks to stabilize the loop. The output of the operational amplifier is run into a differential stage which supplies the charging current for the capacitors in an oscillatory circuit. One side of the oscillatory circuit is used to drive the output transistors.

A summary of the physical characteristics follows:

a) <u>4.5 volt power supply</u>

0.318 cm (0.125 inch) thick glass epoxy terminal and mounting board
Aluminum frame 3.18 cm (1.25 inches) thick
Interconnect wiring beneath board-conformal coat with PRC 1535
Encapsulate parts above board with Ablefoam No. 1 seal connector and PRC 1535 prior to encapsulation.
Volume - 205.5 square cm (31.875 square inches)
Weight - 0.34 Kg (0.75 pound)

b) <u>Variable Voltage Power Supply</u>

158 cm (0.062 inch) glass epoxy printed circuit board
Aluminum frame 3.18 cm (1.25 inches) thick
Interconnect wiring below board
Conformal coat both sides with PRC 1535
Cement board to frame with EC 1614
Volume - 205.5 square cm (31.875 square inches)
Weight - 0.34 Kg (0.75 pound)

c) <u>Phase Change Controller</u>

Aluminum frame 3.80 cm (1.50 inches) thick with metal center web
Insulated terminals soft-wired to connector
Conformal coat wiring side and terminals top side with PRC 1535
Encapsulate modules separately with Stycast 1090
Volume - 283.0 square cm (43.87 square inches)
Weight - 0.79 Kg (1.75 pounds)

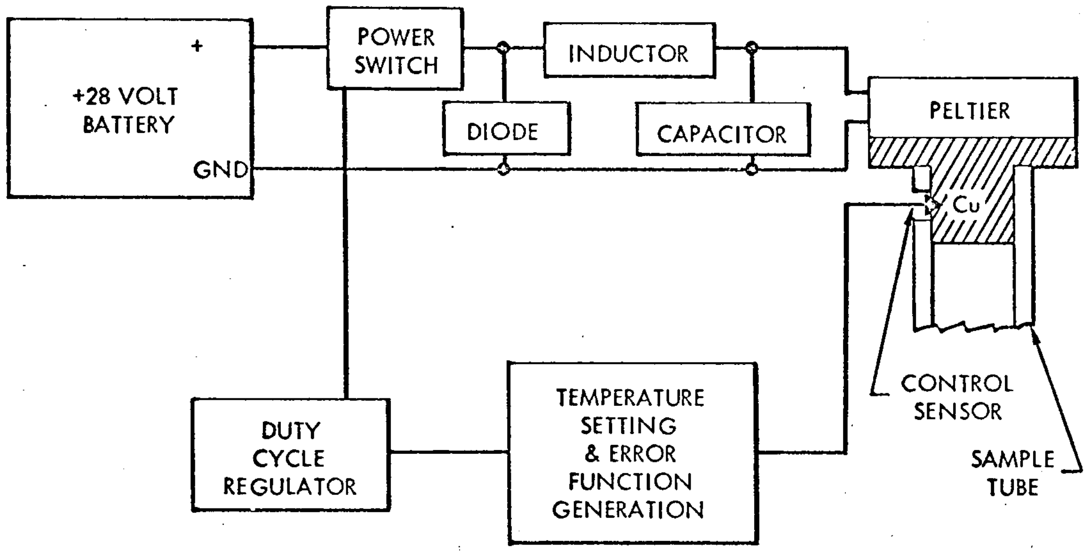


FIGURE 3-23 OBSERVATION UNIT CONTROLLER

3.2.4.3.3 <u>WIRING INTERCONNECT</u> -- Wiring interconnect will be accomplished through a control panel which will be comprised of several switches, indicator lamps, and a display meter. The experiment module will be hard wired together with use of ships (CM/SM) cabling. The switches will include the following:

a) An off-on toggle switch for system power.

b) A pushbutton type START switch which will initiate the start of an experiment run. This switch has a built-in indicator lamp to indicate that the data system is on.

c) A pushbutton switch, Heater Control Override, which will remove heater power in the event the heater controller has not switched off heater power after the prescribed temperature of the experiment is attained. This switch also contains a lamp which indicates heater power on.

d) A pushbutton type stop switch used to terminate observation unit runs and to abort any experiment runs, if necessary, for whatever reason.

e) A three-position rotary switch will select Space PCTR, Sink PCTR, or Observation unit. This switch enables the proper multiplexer and heater control circuits, selects data frame rate, and connects proper signal conditioning amplifiers to display meter.

f) A four-position rotary switch selects the experiment run and identifies the type of material to be studied in the Observation unit, and also may set the gain of the thermocouple amplifiers.

g) A five-position rotary switch to select the control made for the observation experiment thermal electric cooler.

h) A switch to eject the radiator experiment host shield

i) A switch to activate the LN_2 system.

Also, the panel contains a record light which blinks on for a period of 375 milliseconds during the record cycle to indicate a data frame.

3.2.4.3.4 GROUND SUPPORT EQUIPMENT -- The Phase Change Thermal Radiator Flight Experiment will require a basic console to check out the system through development, testing, environmental evaluation, system checkout, acceptance tests and through preflight checkout. In addition to this console, an optional commercial tape recorder could be utilized to transfer the experiment data. Also, a special liquid nitrogen fill system will be required for the experiment. During prelaunch activity a prelaunch monitor shall provide trickle charging for the experiment batteries and will also monitor all critical parameters.

a) GSE Console

The GSE console shall contain external power sources, power monitoring panel, a radiator experiment monitor and control panel, observation experiment monitor and control panel and a data reduction system. The associated digital tape recorder shall record the experiment data for future reference and evaluation. Figure 3-24 is a simplified block diagram showing the basic functions of the GSE Console.

The Power Monitor and Control Panel shall be capable of switching the various voltages from the experiment to a digital voltmeter for accurate measurements. A dc ammeter will monitor the basic +28 volts dc and the -24 volts dc as well as all other power sources. An external load bank will provide maximum loads to each experiment power source. The two experiment monitor panels will control and display the function of each individual experiment. The data reduction system of the GSE will lock onto the sync signal, recognize the experiment and route the binary data to a paper card punch compatible to the IBM system. An optional feature will include conversion of the binary data to BCD format and displaying in a BCD readout. A digital tape recorder can be utilized for recording the data for future review and evaluation of the data. To evaluate the overall data system an accurate 0-5 volt dc source shall be available to substitute for the experiment data inputs for providing a precise value of overall system performance.

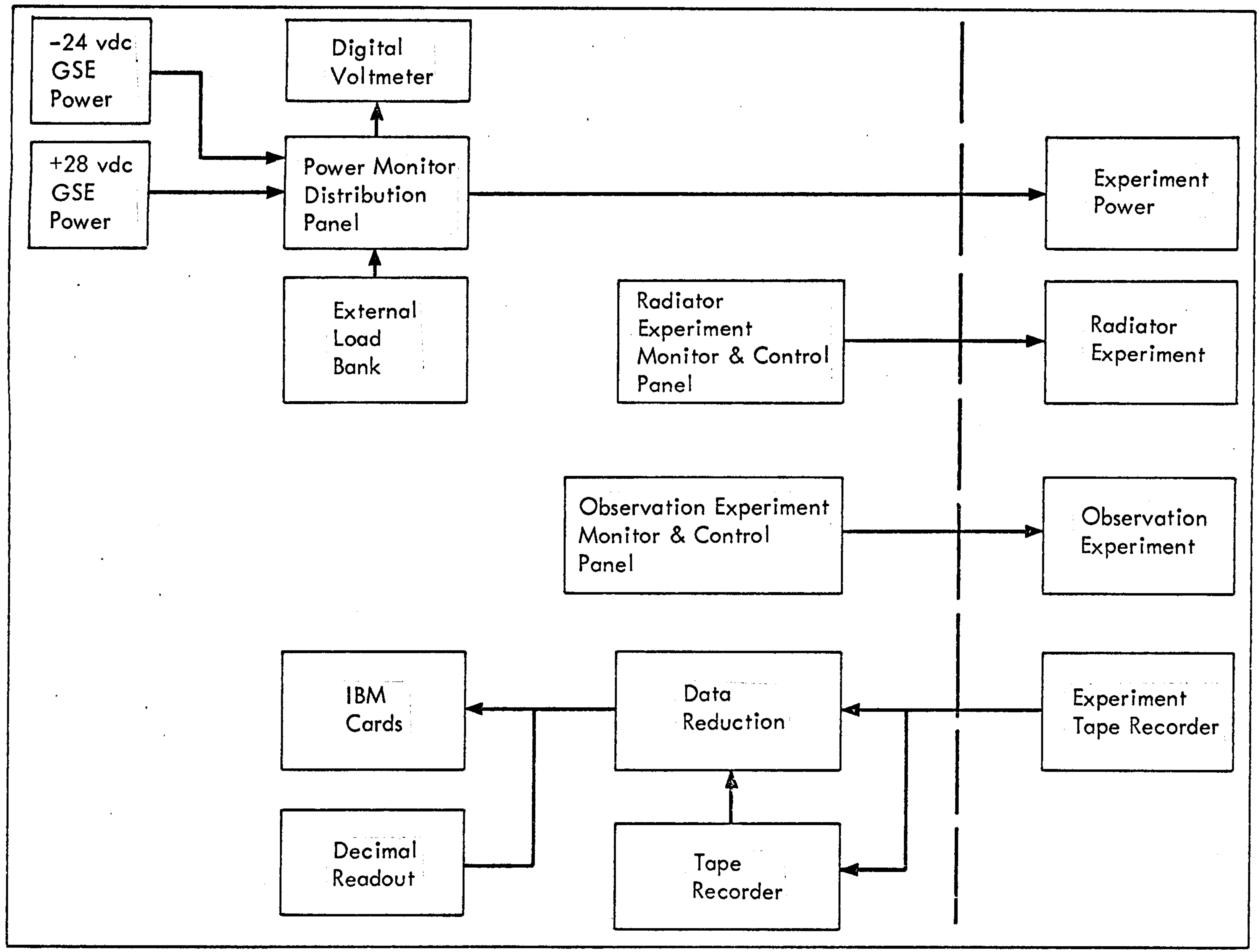


FIGURE 3-24 GSE SYSTEM CONSOLE

b) LN_2 Fill System

The LN_2 Fill System will provide sufficient LN_2 to the sink radiator LN2 storage system for:

1. System cool down
2. System fill
3. System check out
4. Top up system

The LN_2 Fill System shall connect to the PCTR LN_2 system by a quick disconnect insulated line and shall supply power and controls to PCTR LN_2 valves. The fill system will be operated for experiment check out at Northrop or NASA facilities and for prelaunch operations.

c) Prelaunch Monitor

A Prelaunch Monitor GSE shall provide a trickle charge for the experiment batteries and will monitor the critical parameters of the PCTR flight experiment. This unit will be a carry-on test set for use at the launch pad prior to final countdown.

3.2.5 HARDWARE LIST AND END ITEM

A hardware list is shown on figure 3-25. The Master End Item Specification (MEI) is presented in section 12. A hardware tree is presented in figure 3-26.

	Specification No.	Drawing No.
Flight Experiment - Phase Change Thermal Radiator	NSL 67-214	
Flight Experiment - Radiator		142-00100
Module - Radiator Experiment		
Radiator - Space		
Radiator - Simple		
Structure - Mechanical		
Support - Frame		
Shield - Heat		
Subsystem - Liquid Nitrogen		
Flight Experiment - Observation Unit		142-00300
Optical Assembly - Observation Unit		
Tubing - Optics		
Illuminator		
Camera		
Lens		
Piece - Eye		
Film		
Positioner - Test Cell		
Compartment - Electronics		
Panel - Control		
Compartments - Storage, Test Cell		
Box - Storage, Ambient		
Box - Storage, Cold		
Cell - Test		
Support Subsystems		
Subsystem - Data		142-00400
Subsystem - Power & Control		142-00500
Wiring Interconnect - PCTR Flight Experiment		142-00700
GSE - PCTR Flight Experiment		142-00800

FIGURE 3-25 HARDWARE LIST

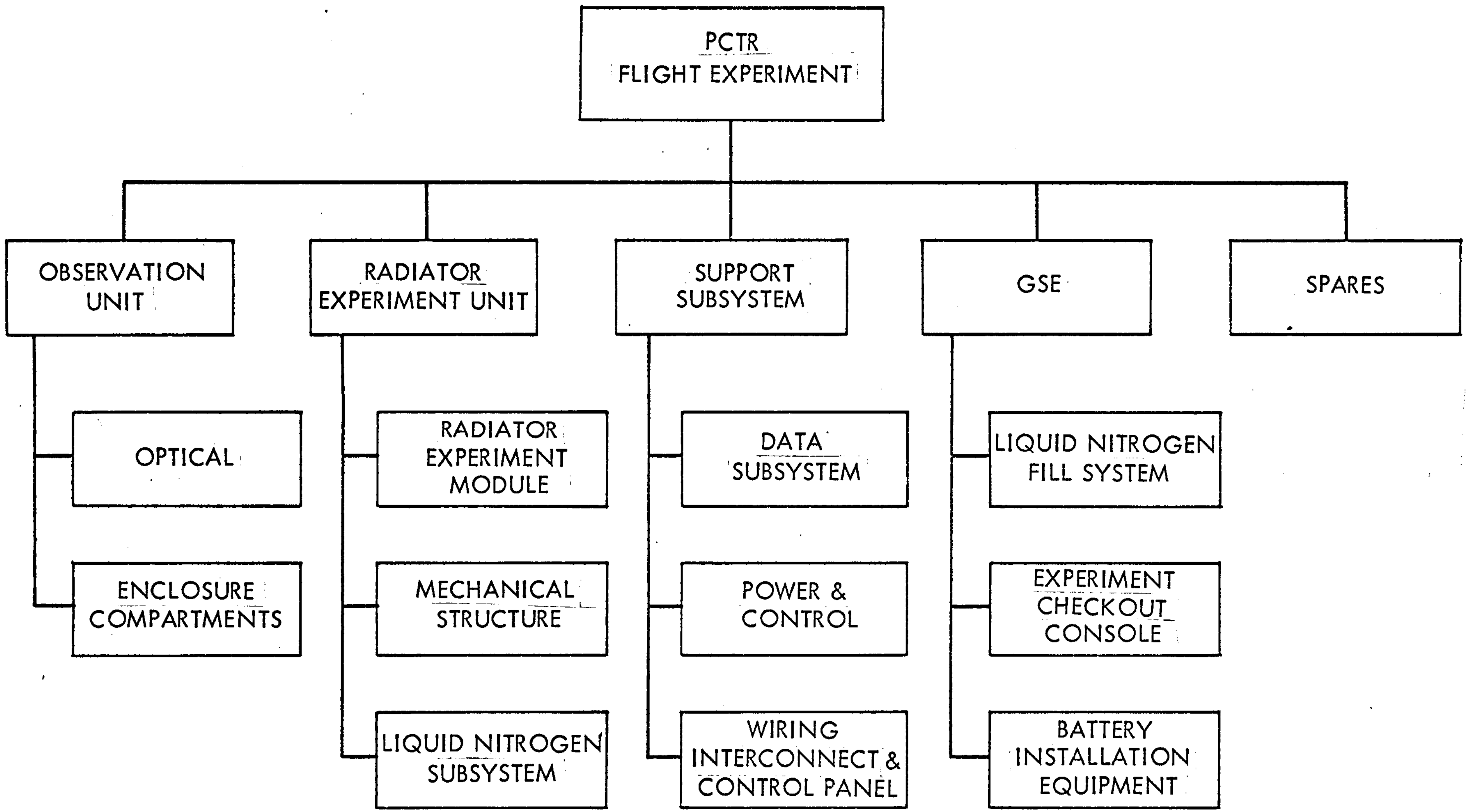


FIGURE 3-26 PCTR FLIGHT EXPERIMENT HARDWARE TREE

3.2.6 TEST REQUIREMENTS SUMMARY (DEVELOPMENT, QUALIFICATION, AND ACCEPTANCE)

An integrated test program for the PCTR Flight Experiment shall substantiate conformance to the following:

a) Design

1) MC-414-0365	7) MIL-W-6858C	13) MSC-EMI-10A	19) MS-33586A
2) MC-999-0007	8) MIL-I-8500B	14) MIL-STD-16C	20) MSFC-STD-271
3) MIL-T-152B	9) MIL-W-8611A	15) MIL-STD-130B(1)	21)
4) MIL-D-2000	10) MIL-I-26600	16) MIL-STD-143A	22)
5) MIL-W-5088C	11) MIL-P-55110A	17) MIL-STD-447	23)
6) MIL-E-6051C	12) NPC-500-1	18) MIL-STD-803A-1	

b) Function

1) NSL-67-203

c) Performance

1) NSL-67-203

d) Qualification

1) NPC-200-3

e) Quality Control

1) NPC-200-3	3) NPC-250-1	5) MIL-HDBK-217
2) NPC-200-4	4) MSC-ASPQ-56A	

f) Acceptance

1) NSL 67-214

Test requirements will be accomplished in accordance with the following philosophy:

a) Preliminary specifications will be released soon after the start of the program. Within 1-1/2 months thereafter, final specifications will be released.

b) Prototype hardware will be procured which will meet all functional, attachment and volumn requirements.

c) Fully qualified hardware will then be procured which will be used for system qualification.

d) Two complete sets of fully qualified hardware will also be procured for the two flight systems.

3.3 Organization

Organization of Northrop personnel for the accomplishment of the Phase Change Flight Thermal Radiator Experiment is shown in figure 3-27.

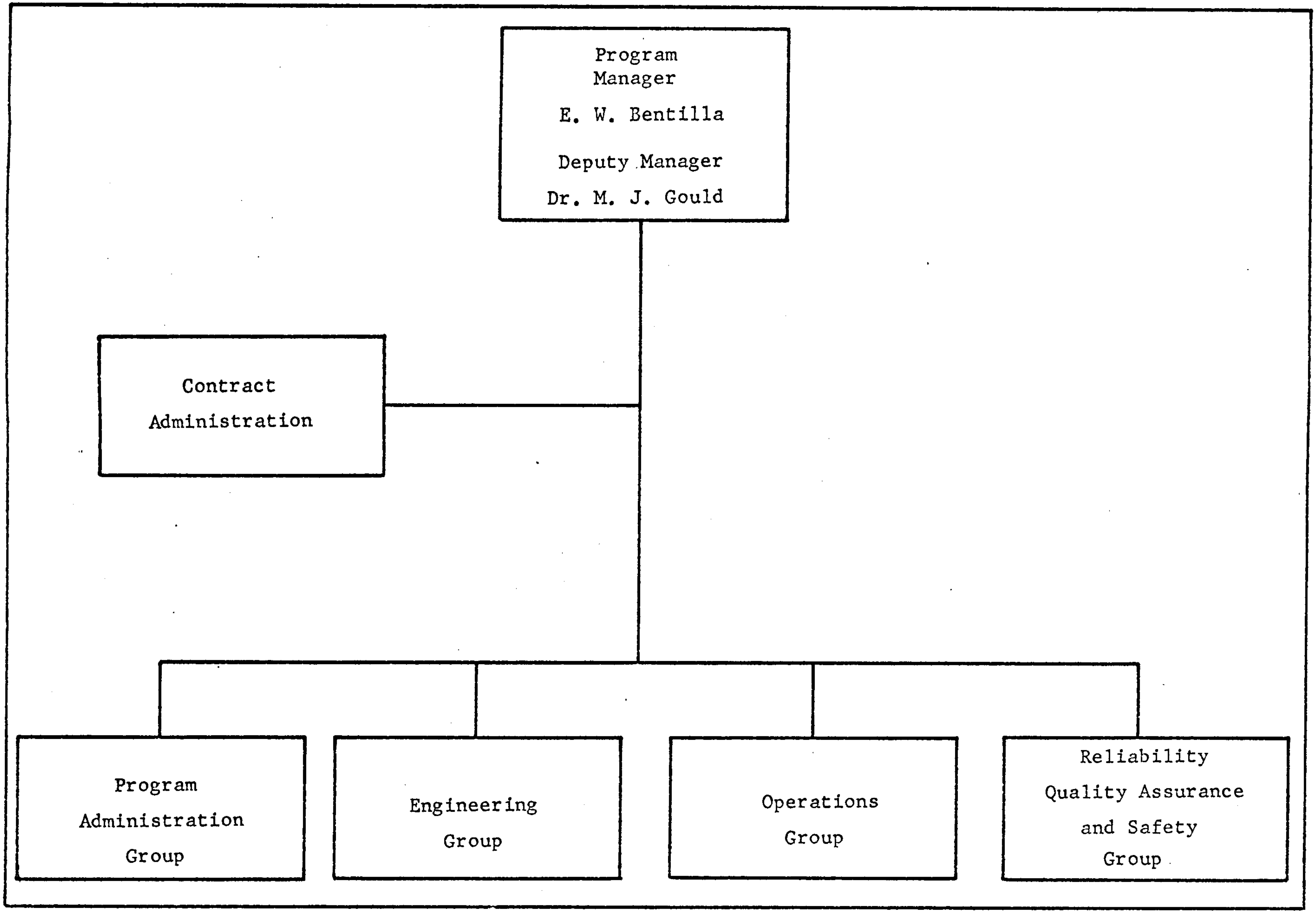


FIGURE 3-27 PCTR PERSONNEL ORGANIZATION

NSL 67-208

MANUFACTURING PLAN

SECTION 4

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

4.0 MANUFACTURING PLAN

4.1 Introduction

4.1.1 PURPOSE

The Manufacturing Plan for the PCTR was developed to define the manufacturing tasks required for fabrication of the Phase D hardware and to establish the organizational structure, procedures, schedules, documentation, and controls necessary to support this activity. The contents of this plan will be updated during the Phase D program and used to implement manufacturing programming and control activity, planning functions, detail scheduling, and tooling activities.

4.1.2 PRODUCT DESCRIPTION

The Phase Change Thermal Radiator Flight Experiment will include the following units:

- Observation Unit
- Radiator Experiment Unit
- Power Supply Unit
- Ground Support Equipment
- Spares

The descriptive content of the flight units, shown in PCTR Block Diagram (Figure 4-1), as follows:

4.1.2.1 *Observation Unit

Optical Subassembly: Includes the optics tubing, illuminator, lens, eyepiece, camera, film, test cell, test cell positioner, and thermocouple assembly.

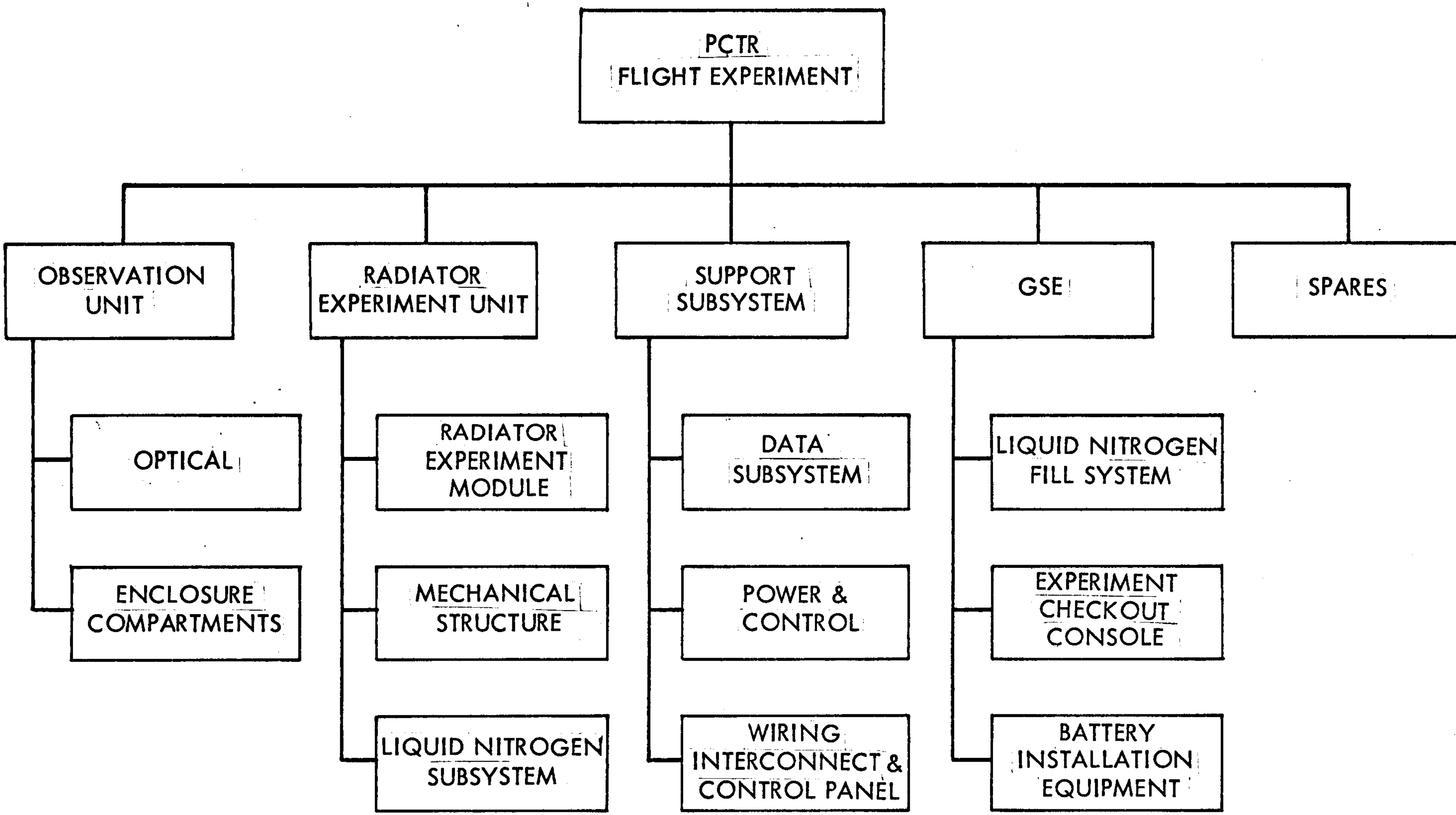


FIGURE 4-1 BLOCK DIAGRAM PCTR FLIGHT SYSTEM & SUPPORT EQUIPMENT

Enclosure Compartments:

Includes packaging enclosure for the entire Observation Unit which will have compartments for above subassemblies along with ambient and cold storage compartments for test cells.

4.1.2.2 *Radiator Experiment Unit

Radiator Experiment Module:

Includes the space radiators (both the PCTR and simple radiators) and the sink radiator.

Mechanical Structure:

Will consist of a frame support for the space radiator and an ejectable heat shield.

Liquid Nitrogen Subsystem:

Consists of a liquid nitrogen storage tank, a control subsystem and a plumbing subsystem.

4.1.2.3 Support Subsystem

* This subsystem includes the data packages physically located in the Observation Unit and the Radiator Experiment Unit, in addition to the power supply and interconnect wiring. The subsystem is categorized as follows:

-Data Subsystem: This includes a programmer, the space PCTR data subsystem and heater control, the Sink PCTR

Power & Control Subsystem:

This includes two primary silver-sinc batteries and the power supply conversion and regulation electronics.

Wiring Interconnect & Control Panel:

Consists of the Control Panel electronics and the interconnect wiring for the total PCTR Flight Experiment.

4.1.2.4 Ground Support Equipment

Ground Support Equipment (GSE) will consist of:

- Liquid Nitrogen Fill System
- Experiment Checkout System
- Battery Installation Equipment

These items of GSE shall be furnished for use in the MSOB at Kennedy Space Center.

4.1.2.5 Spares

Adequate spares will be included to support the maintainability of the PCTR Flight Experiment System during checkout and pre-launch ground operations at KSC.

4.1.3 DELIVERABLE PRODUCTS

The major Contract End Items (CEI) to be produced by the manufacturing activity during the Phase D Program are:

Prototype Engineering System
(1 required)

This is a complete operational PCTR system used by Engineering to verify and checkout the physical and functional characteristics of the prototype configuration.

Qualification Subsystems:

This includes the fabricated electronics and interconnect wiring which are contained in the Support Subsystems of the PCTR Flight Experiment System.

Qualification System:
(1 required)

These complete PCTR systems, fabricated to the specifications and configuration of the flight systems, using qualified parts and components, will be used to conduct the system qualification tests.

Flight System:
(2 required)

These are complete operational PCTR Systems, fabricated and assembled to flight system specifications using qualified parts and components.

GSE:
(1 required)

The GSE equipment consists of a Liquid Nitrogen Fill System, an Experiment Checkout Console and Battery Installation Equipment.

Elements of the system to be produced by Manufacturing for the major Contract End Items are identified in the Product Matrix, Figure 4-2. Numbers in the Manufacturing Task Column indicate quantities to be manufactured for each PCTR system. The level of effort shown in the Fabrication Column includes both procured and fabricated hardware items. The Make or Buy List, of the Phase "D" proposal, (Section 4.10), lists the procured components

Manufacturing Tasks

PCTR System / Hardware Element	Development Model	Qualification Model	Flight Test Model
Experiments			
Observation Unit	1	1	2
Space Radiator	1	1	2
Sink Radiator	1	1	2
Support S/S			
Power & Control S/S	1	2	2
Liquid Nitrogen S/S	1	1	2
Data S/S	1	2	2
Camera & Optical S/S	1	1	2
Structure S/S	1	1	2

FIGURE 4-2 PCTR PRODUCT MATRIX

4.2 Responsibility

This Manufacturing Plan encompasses the activities required to manage, plan, tool, fabricate, assemble, and control the development of PCTR test and flight hardware.

4.2.1 ORGANIZATION

These activities will be performed by the Manufacturing Branch of the PCTR Operations Group. The organizational structure of the Operations Group is illustrated as Figure 4-3 and the Manufacturing Branch and Associated Functions as Figure 4-4.

Figure 4-5 shows the relationship of the Manufacturing Branch to other segments of the PCTR program organization. In addition, this figure charts the flow of documents through this organization.

4.2.2 MANUFACTURING CONTROL PROCEDURES

Manufacturing Engineering will exercise full manufacturing management responsibility for assuring compliance with performance, cost, and schedule during fabrication and assembly of the PCTR hardware. The cognizant manufacturing engineer also assures that all materials (hardware and software) needed to accomplish fabrication, assembly, and test of the PCTR are available as needed.

The cognizant manufacturing engineer will establish and coordinate the elements of the Phase "D" Manufacturing Plan with engineering, tooling, fabrication, and assembly to assure program continuity and compliance. He will also, in conjunction with other elements of the PCTR organization, establish a priority system for the release of engineering drawings, based on the planned assembly sequence. Each drawing is coded prior to release to assure sequential action through engineering, tooling, quality control, fabrication, assembly, and test.

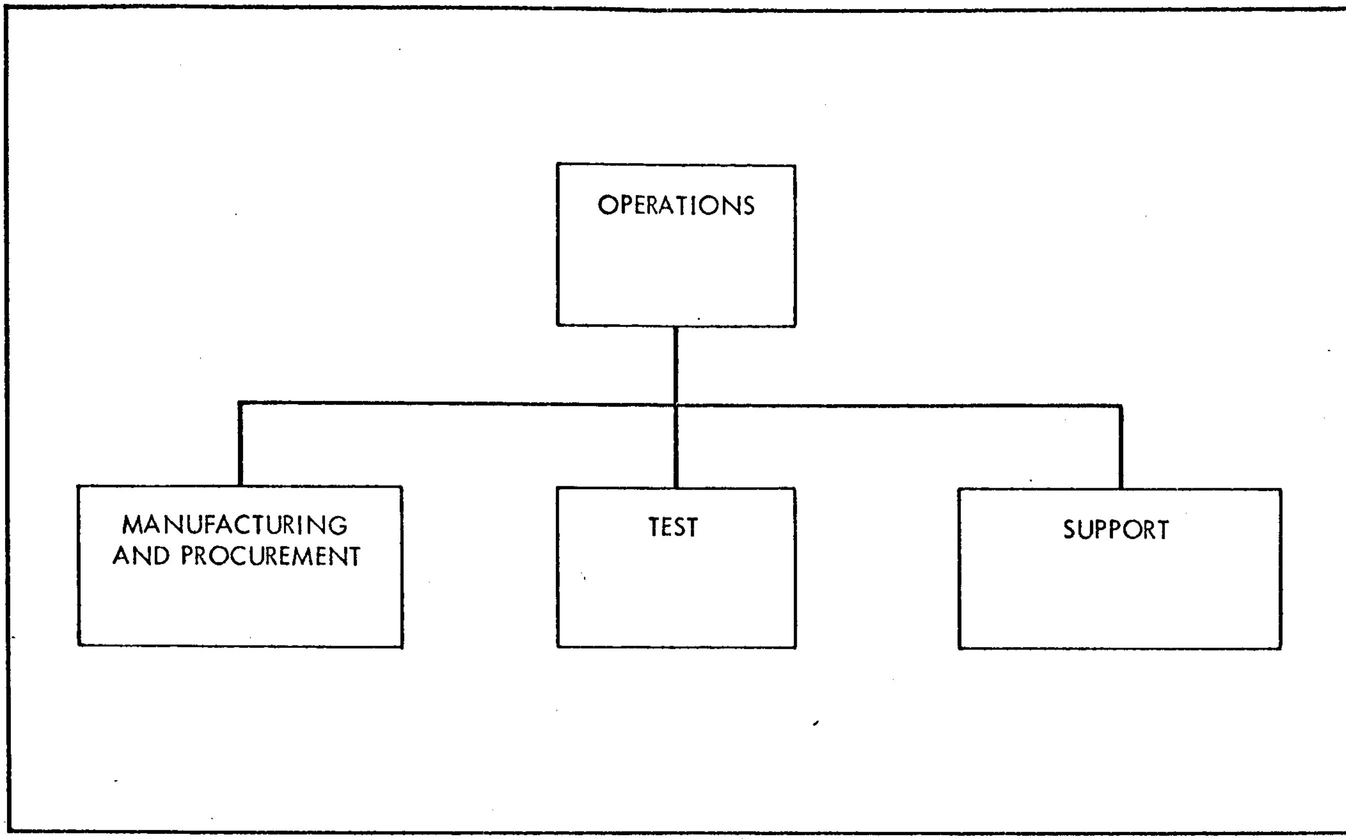


FIGURE 4-3 ORGANIZATION - OPERATIONS GROUP

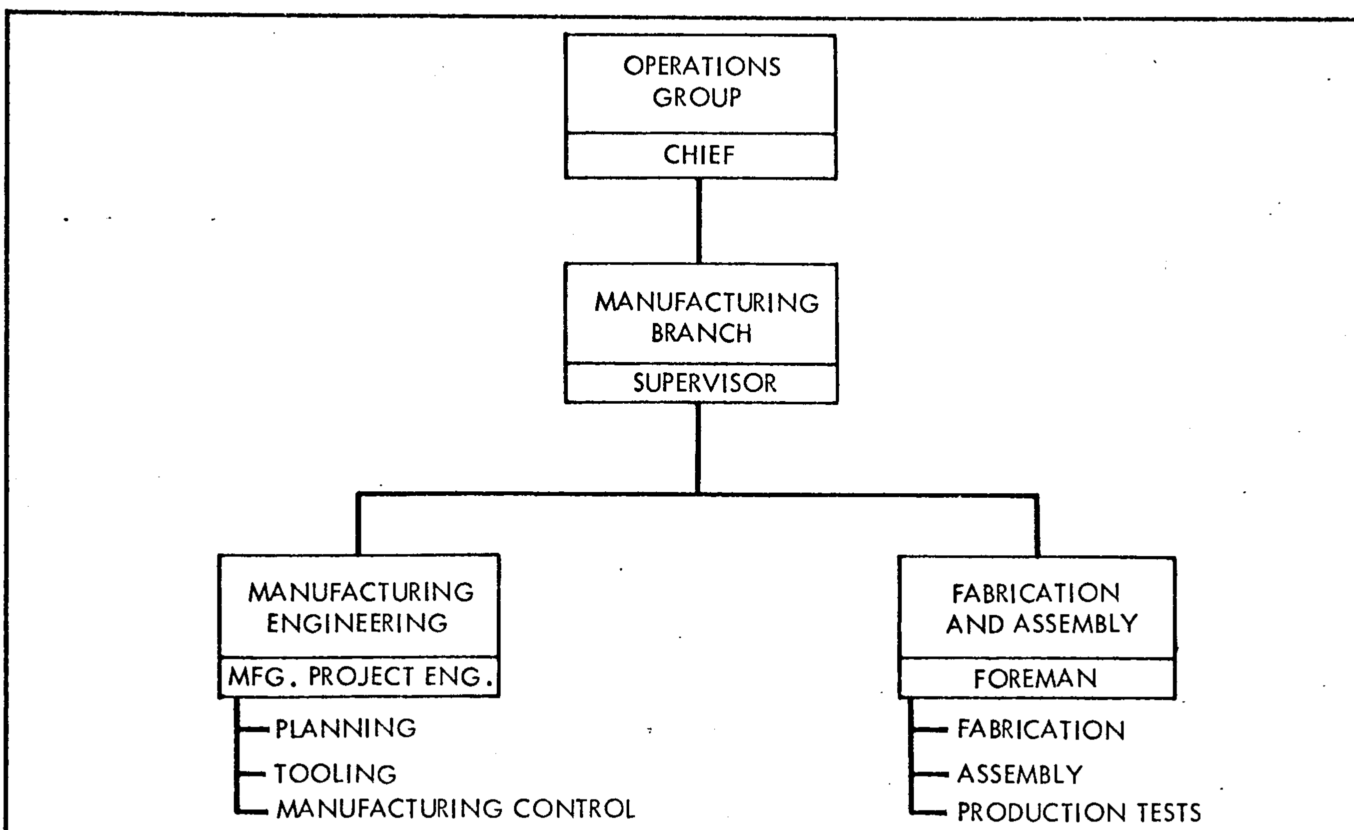


FIGURE 4-4 ORGANIZATION AND FUNCTIONS MANUFACTURING BRANCH

A manufacturing planner, assigned to the program and under the direction of the cognizant manufacturing engineer, will analyze all engineering drawings, specifications, and documents to determine the fabrication, subassembly, assembly, and installation operation requirements.

Planning paper denoting detailed step-by-step fabrication and processing procedures is created by the planner for use by the manufacturing shops on all items to be fabricated and subassembled by Northrop. The paper to be used on the PCTR Program is a standard Northrop planning form known internally as a Production Order. Figure 4-6 shows a typical order. These orders provide authority and instructions for the fabrication and subassembly of parts per engineering requirements and planned conditions on limited production type programs. They also provide for rework or delivery of parts, supply a means whereby Timekeeping and Accounting may compile cost factors of required operations, and also provide a statistical record of activities performed and results obtained. Data entries are completely compatible with Northrop's Automated Operations Control System, Budgeting Systems, and Integrated Cost Controls.

Final assembly and installation procedures for the PCTR will be established and controlled through the use of Assembly Inspection Books which are created by Planning and issued as individual books for each PCTR. The planning paper contained in the Assembly Inspection Books provides a complete list of parts, detailed assembly, and installation instructions, and a historical record of production inspection, and customer "buy-off" for each specific unit manufactured. Figure 4-7 through 4-11 shows the contents of a typical assembly inspection book which subsequently forms a portion of the item's Acceptance Data Package.

The PCTR Program will require concurrent activity in design, development manufacture, and test. It is anticipated that there will be an engineering

ODUCTION ORDER-PRODUCTION ORDERING COPY
TRONICS FORM 46A (11-60)

OPERATION SHEET

SPLIT ORDER
EST. TOOL HOURS | BY

TOOL ABREV.
PART NO.

IN WORK | COMPL.

RT ME | SCHED. CODE

UE | ISSUE DATE | SUPERSEDES ISSUE OF | EFF | PG OF

S ISSUE ITTEN BY | PHONE | ENG CHGS

EVISION NOTES:

A/C CODE | DV | SALES ORDER | DASH | QUANT. ORDER

PART NO. | UNIT REQMTS. L R | PROD. NEXT ASSEM. | MODEL

ATERIAL

ORGN.

VARIABLE INSTR. | DATE

ROD. ORGN.	ORGN. & INSP. SIGN OUT QTY.	DATE	BY	OPER. & EQUIP. CODE	OPERATION & TOOL PLANNING	SET UP / PARTS INV. TYPE	RUN L	R	TOOL NUMBER AND ABBREV.	ORGN. TO MAKE TOOL	TOOL EFFEC. ON UNIT	TOOL SET BACK	TOO CHG

FIGURE 4-6 SAMPLE - PRODUCTION ORDER

MANUFACTURING ASSEMBLY
AND ACCEPTANCE SHEET
FORM 76.37A (R.4-60)

TITLE

PAGE 1 OF 1

DRAWING NO.

LINE NO.	JOB NO.	PART TYPE	NO. REQ'D. L	NO. REQ'D. R	JOB DESCRIPTION PART NO.	JOB DESCRIPTION PART NAME	JOB DESCRIPTION REMARKS	UNIT SHORT SETUP	INVEN. RUN	PROD. O.K.	DATE	CO. O.K.	DATE SOK. NO.'S	CO. O.K.	CUST. O.K.	BUY OFF CODE
1.																
2.																
3.																
4.																
5.																
6.																
7.																
8.																
9.																
10.																
11.																
12.																
13.																
14.																
15.																
16.																
17.																
18.																

PLANNER	INSP. PLANNER	CHECKED BY	DATE	EFFECTIVITY	PROJECT	PAGE OF	O.K. TO FILE	DRAWING NO.
					SECTION NO.	ISSUE NO.		MF. SERIAL NO.

EFFECTIVITY OF CHANGE AND REVISION NOTES:

COPIES TO

(DO NOT WRITE BELOW THIS LINE)

FIGURE 4-7 MANUFACTURING ASSEMBLY AND ACCEPTANCE SHEET

FORM 27-91 (R.9-52)

1. IF SQUAWK SHORTAGE, NOTE SQUAWK NUMBER UNDER PAGE AND ITEM........ EXAMPLE........ PAGE & ITEM: SQ / 37
2. IF SHORTAGE ORIGINATED ON SHOP ORDER, NOTE "SO" UNDER BOOK NUMBER.
3. IF REMOVAL ITEM SHORTAGE, NOTE "REM" AND BOOK NUMBER UNDER BOOK NUMBER AND REFERENCE PAGE AND ITEM NUMBER OF REMOVAL CARD.
4. SHORTAGES RESULTING FROM EOS WILL HAVE THE EO NUMBER LISTED UNDER "ASSEMBLY FROM WHICH SHORTAGE FIRST ORIGINATED" COLUMN.

NO.	SHORTAGE SOURCE			SHORTAGE PART NO.	QTY.	DESCRIPTION OR NAME OF SHORTAGE	ASSEMBLY FROM WHICH SHORTAGE FIRST ORIGINATED	DATE, ENTERED BY	INSP. APPROV.	DATE, WORKED BY	INSPECTION		
	BOOK NO.	POS. NO.	PAGE & ITEM								DATE	1ST	ACCP.
1									315	BB		315	315
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													

LINE TITLE	ASSEMBLY NO.	MODEL	SHORTAGE SHEET NO.	COMPLETED	INSPECTION BOOK	PLANE SERIAL
Structure Assem Base S/S	136-20000	ALSD	___ OF ___	8/31/6		

FIGURE 4-8 SHORTAGE SHEET

LINE	DRAWING NO.	E.O. OR DRAWING CHANGE LETTER	POSTED		PROD. OK	INSP. OK		NOTES
			DATE	BY		STAMP	DATE	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

ADVANCE DRAWING CHANGE NOTICE AND E.O. LIST	QUALITY CONTROL TO MAKE THESE ENTRIES			PAGE ______	OK TO FILE	PROGRAM	SERIAL NO.
	SERIAL NO	VENDOR'S PART NO.	INSTALLED ON UNIT NO.				

FIGURE 4-9 DRAWING CHANGE NOTICE AND EO LIST

REMOVAL RECORD
Form 27-92 (R.2-60)

(INSPECTOR MUST ALWAYS NOTE DATE ABOVE HIS STAMP IMPRESSION)

ITEM	PART NO. / PART NAME	REASON FOR REMOVAL	OK TO REMOVE				OK TO INSTALL				REINSTALLATION				OPERATION	
			SER. NO.	MECH.	DATE INSP.	USAF	SER. NO.	MECH.	DATE INSP.	USAF	SER. NO.	MECH.	DATE INSP.	USAF	MECH.	DATE INSP.
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																

ASSEMBLY NO.______ ASSEMBLY NAME Structure Assem Base S/S ______ SERIAL NO.______

BOOK NO.______ REMOVAL RECORD NO.______ MODEL______ COMPLETED______

FIGURE 4-10 REMOVAL RECORD

INSPECTION PICK-UP
FORM 27-89 (R. 6-59)

(SQUAWKS TO BE NUMBERED CONSECUTIVELY - USE ONLY BLUE/BLACK INK - STAMP IMPRESSIONS MUST BE LEGIBLE)

SQK. NO.	REFERENCE		DISCREPANCY	REPORTED		ATTENDED TO		ACCEPTED	
	POS. / PAGE	ITEM	STATE SPECIFIC DEGREE OF ERROR. GIVE EXACT LOCATION - STATION NUMBER - WATER LINE - LEFT OR RIGHT HAND - INBOARD OR OUTBOARD - UPPER OR LOWER - INCLUDE PART NUMBERS.	DATE	BY	DATE	BY	DATE	BY

BOOK NUMBER ______ PAGE ______ MODEL ALSD ______ UNIT SERIAL NO. ______ OK TO FILE ______

PREP. FOR FLIGHT NO. ______ OTHER: ______

CHECK ONE: (√) ☐ PALMDALE ☐ EDWARDS AIR FORCE BASE

(CONTINUED ON REVERSE SIDE)

FIGURE 4-11 INSPECTION PICKUP

change factor throughout a significant time-segment of the program period. Therefore, it is mandatory that the engineering Drawing Release and Change Control System embody a "fast reaction time" technique for the rapid assimilation of changes. In addition, the system for drawing release and change control must retain a strong influence over reliability, schedule, and cost.

A suitable change control and verification system is currently in operation throughout Northrop's operating segments. It places the responsibility for control of change within a Change Review Board (CRB) empowered to make decisions to the degree required. The CRB meets daily, or on a "call" basis, so that all engineering changes can be processed rapidly. Manufacturing is represented on the CRB through the cognizant manufacturing engineer with the authority and responsibility for making immediate decisions pertinent to fabrication and assembly operations.

The budgeting system now used at Northrop to budget, report, and control overhead costs will be used to control indirect costs within the PCTR manufacturing organization.

Direct budgets for fabrication and assembly are allocated to the individual shops by manufacturing release; in the assembly area, by individual job. These budget targets cover the anticipated total statement of work. The cognizant manufacturing engineer works with each shop manager to establish the target budget, taking into consideration such factors as effect of lot size, impact of schedule and tools, shop progress curve experience, past shop performance, and shop cost reduction capability. The shop manager is, therefore, instrumental in setting his own target. He understands the work task and establishes the means of measuring performance. The basic management tools used to visualize his progress are weekly Integrated Cost Control (ICC) reports that match labor, material, and overhead expenditures against target budgets. The direct labor cost control reporting techniques are applicable both to periodic activities, such as fabrication and tooling, and to continuous (line) activities, such as assembly operations.

Operations and services required from other Northrop divisions are furnished under the terms of an Interdivisional Work Order. All paperwork shows the IWO number and special sales order assigned. The sales order is utilized by the division concerned to identify the specific work charges accruing to that specific task. All IWO work is received and shipped through a central control terminal where inventory records and shortage controls are maintained. Shortage reports are furnished to the Manufacturing Engineering Office for follow-up and coordination with the division performing the work. At this point, a priority rating system is used to note the shortage and schedule, and to place the item in work ahead of less critical items. Priority items are expedited and high-lighted in Management Reports.

4.2.3 TOOLING APPROACH

Since a small number of PCTR units are to be manufactured, only those tools which are mandatory for producing a qualified and reliable article will be fabricated by the tooling organization. However, in programs such as this, it is Northrop's practice to fabricate simple tooling aids (as required) to supplement the planned program.

Generally, the PCTR subassembly and subsystem fabrication and assembly work will be accomplished with general purpose tools and equipment. The tooling will be consistent with technical requirements, and will be simple, economical, and as easy to handle and store as possible. Duplication of tooling will be avoided. Multiple usage of individual tooling will be employed where practical.

Where fabrication tooling and assembly jigs and fixtures required for this program are critical as to schedule, early planning will be instigated. Key planners and manufacturing engineers will be physically located with, or in the immediate proximity of, the cognizant engineers. This permits the early release of tool design drawings on critical items prior to the release of fabrication drawings.

All major assembly fixtures, master control gages, check fixtures, and handling equipment required to support of the PCTR Program will be designed by the Tool Design segment. Tool design drawings are provided by this segment for the more complex machine tools, test tools, and specialized fabrication and installation tooling.

The determination by the cognizant manufacturing engineer and planner of the tooling needed to support the fabrication, subassembly, assembly, and installation activities are based on the following ground rules:

a. Machine tools are provided only in those cases where hand layout and standard machine setups do not meet required tolerances, nor product parts of assured quality.

b. As a general rule, small subassembly tools are not furnished unless they could eliminate requirements for a duplicate major assembly fixture, or unless they are necessary to meet the quality and reliability requirements of the finished article.

c. Handling equipment for in-plant handling of components is ordered only when alternate methods cannot suitably perform the job, or where excessive handling may compromise the quality of the assembly.

d. The test equipment developed during in-plant design, qualification, and functional testing is utilized throughout the manufacturing phase where possible. Again, such equipment is duplicated as a contract tool if the original equipment cannot be used due to prior commitments.

e. Mechanical and electronic inspection fixtures are designed and fabricated to support receiving inspection if the part or component to be tested cannot be readily inspected with existing standard test equipment, purchased duplicate vendor test equipment, or designed and developed ground support equipment. In any case, the ultimate quality and reliability of the detail or component part being inspected and tested dictates the requirement for a check or inspection fixture.

4.3 Fabrication and Assembly Tasks

The Fabrication and Assembly organization will perform all operations necessary to fabricate, assemble, and conduct production tests on the PCTR, prototype model, and flight equipment required to meet Phase D contractural obligations. Specific hardware items and the quantities of each item to be producted are described in Sections 4.1.3 and are shown in the Product Matrix Figure 4-2.

Workmanship for the PCTR Flight Experiment, including subsystem parts and equipment, will be to high quality aerospace standards with particular attention directed towards: freedom from blemishes, burrs, and sharp edges; required tolerances on dimensions; adequate and correct marking identification on parts; thoroughness and neatness of cleaning, soldering, welding, and wiring installations; satisfactory tightness and proper torque of assembly screws and bolts. All manufacturing materials, workmanship and finished hardware will comply with the PCTR Master End Item Specification (NSL 67-214).

Personnel performing soldering operations will be certified to compliance with NCP200-4 and both structural and electronic welders will be certified to comply with both military and Northrop specifications. Sample electronic welds will be tested in accordance with quality control requirements to assure verification and maintenance of appropriate weld schedules.

4.4 Testing

4.4.1 PRODUCTION CHECKOUTS

Production checkouts are the in-line manufacturing verification of the form, fit, and function of PCTR parts, components, and subsystems prior to acceptance testing. These checkouts are performed under cognizance of Quality Control and in accordance with the requirements of NASA Document NPC 200-2.

4.4.2 ACCEPTANCE TESTS

Acceptance tests will be performed on the PCTR flight articles to demonstrate that the assembled subsystems exhibit functional characteristics within the tolerances of the design specifications. The performance capability of the flight articles with respect to actual mission usage will comply with the performance specification.

Specific tests to be performed for acceptance verification are listed in the Test Plan (NSL 67-206)

4.5 Schedules

The schedule for PCTR manufacturing and procurement activities is shown in Figure 4-12.

4.6 Make or Buy Plan

4.6.1 MAKE OR BUY POLICY

Make or Buy policies and decisions of the Northrop Corporation are administered in accordance with ASPR 3-902. A Make or Buy Board, chaired by the Vice President and Assistant General Manager of Northrop Systems Laboratories, reviews all programs of contract value over $500,000 which involve deliverable hardware or the fabrication and assembly of laboratory prototypes. The decisions of this board are made after a detailed study of the many factors involved, such as:

- In-plant capability and experience in the design, tooling, and manufacture of substantially similar items.
- Fabrication requirements which may directly or indirectly establish the need for changing or expanding existing facilities, or for the acquisition of new equipment.
- Overall effect on cost.
- The effects upon workload or capacity due to the specific program being evaluated against other in-house programs.

At the time of this review, the Make or Buy Board also designates items which are to be considered as subcontract on the program. A subcontract item is one which, because of special significance, complexity, cost, or for other reasons, requires greater control than normal material procurement action. This control is applied in the area of engineering and procurement through special techniques of source selection, evaluation, and administration.

The Make or Buy Board appoints a Source Selection Committee to handle all activities leading to the selection of a successful subcontractor. This Source Selection Committee is selected from middle management, or higher, and assists the procurement group in approving lists of potential bidders, preparation of quotations, implementing supplier surveys, evaluating submitted proposals, and making the final recommendations for subcontractor selection to the Make or Buy Board for approval and decision. After final approval of selected subcontractors by the Make or Buy Board, the results are forwarded to Northrop's Corporate Office for review by the Senior Vice President of Manufacturing - Administration.

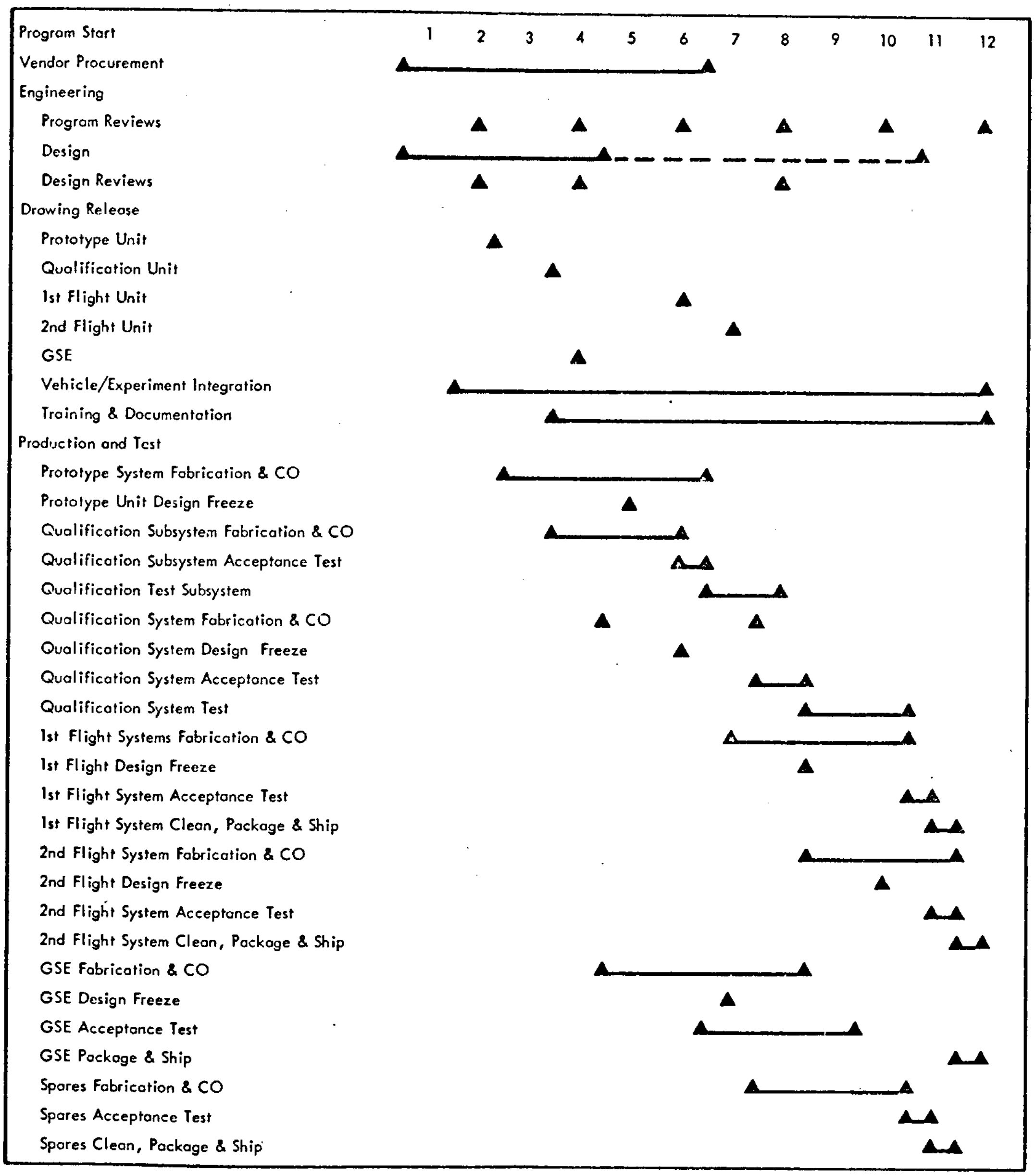


FIGURE 4-12 PHASE IV PCTR FLIGHT EXPERIMENT PROGRAM SCHEDULE

Parts are defined as one piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of designed use. A component is an assembly or combination of parts, subassemblies, or assemblies mounted together to perform a design function and which can be disassembled into discrete parts without destruction of designed use.

Part, material, and component selection criteria are grouped into two categories of hardware. These categories and end item classifications are presented as Figure 4-13.

Deviations from these criteria may be obtained for reasons of schedule and/or cost, if adequate justification can be provided to NASA and NASA approval can be obtained. Requests for waiver are directed to the Northrop Reliability Groups for approval and transmittal to NASA.

All parts and materials will be selected from the Northrop PCTR Approved Parts and Materials List (APML), and will be in accordance with the criteria of the End Item Classification Chart (Figure 4-13).

Schedule, cost, and qualification confidence will be considered in the selection of all parts and materials which must be space qualified. Each consideration is of equal importance and without general preference. The order of confidence to be utilized in selecting a part or material is presented in Tables 4-1 and 4-2, respectively, under "Order of Preference" column. Any order greater than 4 for parts or 5 for materials requires waiver approval from NASA. The last column status code employed entitled "Reference 1, Qualification Status Code Code," is a listing of the qualification status code employed in the NASA Apollo Spacecraft Parts and Materials Program, Master File Report (Reference 1).

Reference 1:
Apollo Spacecraft Parts and Materials Program, Master File Report; Parts Identification Index. Materials Identification Index, Part Name Index; January 7, 1966; National Aeronautics and Space Administration, Manned Space Center, Houston, Texas.

END ITEMS / PARTS, MATERIALS, AND COMPONENTS SELECTION CRITERIA CATEGORY	STRUCTURE SIMULATOR			TRAINING UNITS			ENGINEERING DEVELOPMENT MODEL & SIMULATOR THERMAL MECHANICAL			QUALIFICATION MODELS & FLIGHT MODELS		
	PARTS	MATERIAL	COMPONENTS	PARTS	MATERIALS	COMPONENTS	PARTS	MATERIALS	COMPONENTS	PARTS	MATERIALS	COMPONENTS
MIL SPECIFICATIONS NOT REQUIRED	X	X	X									
MIL SPECIFICATIONS				X	X	X						
MIL SPEC TYPE MAY BE USED IF FUNCTIONAL CHARACTERISTICS CAN BE VERIFIED AS REPRESENTATIVE OF HARDWARE USED IN FLIGHT SYSTEM.							X	X	X			
SPACE QUALIFIED BY TEST AND/OR SIMILARITY, AS APPROVED BY NASA.										X	X	X
SPACE QUALIFIED AT HIGHER LEVEL OF ASSEMBLY ON ALSD PROGRAM WHEN ADEQUATE JUSTIFICATION CAN BE PROVIDED AND NASA APPROVES.										X	X	X
SPACE QUALIFY STANDARD TYPES IN-HOUSE TO BURN-IN AND SCREENING SPEC. APPROVED BY NASA										X	X	X

NOTE: THESE CATEGORIES ARE MINIMUM QUALIFICATION REQUIREMENTS. DEVIATIONS MAY BE CONSIDERED ON THE BASIS OF AVAILABILITY AND/OR COST PROVIDING ADEQUATE JUSTIFICATION IS PRESENTED AND NASA APPROVAL IS GRANTED.

FIGURE 4-13 END ITEM CLASSIFICATION

TABLE 4-1 PART SELECTION - ORDER OF PREFERENCE

Order of Preference	Definition	Reference 1 Qualification Status Code
1	Qualification not required	1
2	Qualification by test - qualified	46
3	Qualification by similarity - qualified	36
4	Qualification by similarity and test - qualified	76
5	Qualification by test and data from other applications - qualified	86
6	Qualification from data from other applications - qualified	56
7	Qualification as part of higher assembly - qualified	26
8	Qualification by test - test completed	44
9	Qualification by similarity - evaluation completed	34
10	Qualification by similarity and test - test or evaluation completed	74
11	Qualification by test and data from other applications - test or evaluation completed	84
12	Qualification by data from other applications - evaluation completed	54
13	Qualification as part of higher assembly - evaluation completed	24
14	Qualification by test - qualification or approval incomplete	42
15	Qualification by similarity - qualification or approval incomplete	32
16	Qualification by similarity and test - qualification or approval incomplete	72
17	Qualification by test and data from other applications - qualification or approval incomplete	82
18	Qualification as part of higher assembly - qualification or approval incomplete	22
19	Qualification by data from other applications - qualification or approval incomplete	52
20	Qualification by test - in test	48
21	Qualification by similarity - in evaluation	38
22	Qualification by similarity and test - in test or evaluation	78
23	Qualification by test and data from other applications - in test or evaluation	88
24	Qualification by data from other applications - in evaluation	58
25	Qualification as part of higher assembly - in test or evaluation	28
26	Qualification by test - test not begun	43
27	Qualification by similarity - evaluation not begun	33
28	Qualification by similarity and test - test or evaluation not begun	73
29	Qualification by test and data from other applications - test or evaluation not begun	83
30	Qualification by data from other applications - evaluation not begun	53
31	Qualification as part of higher assembly - test or evaluation not begun	23
32	Others	

TABLE 4-1 (Concluded)

Order of Preference	Definition	Reference 1 Qualification Status Code
31	Approval by evaluation - evaluation not begun	63
32	Qualification by similarity and test - test or evaluation not begun	73
33	Qualification by test and data from other applications - test or evaluation not begun	83
34	Qualification by data from other applications - evaluation not begun	53
35	Qualification as part of higher assembly - test or evaluation not begun	23
36	Others	

TABLE 4-2 MATERIAL SELECTION - ORDER OF PREFERENCE

Order of Preference	Definition	Reference 1 Qualification Status Code
1	Materials approval not required	1
2	Qualification by test - approved	47
3	Qualification by similarity - approved	37
4	Approval by evaluation - approved	67
5	Qualification by similarity and test - approved	77
6	Qualification by test and data from other applications - approved	87
7	Qualification from data from other applications - approved	57
8	Qualification as part of higher assembly - approved	27
9	Qualification by test - test completed	44
10	Qualification by similarity - evaluation completed	34
11	Approval by evaluation - evaluation completed	64
12	Qualification by similarity and test - test or evaluation completed	74
13	Qualification by test and data from other applications - test or evaluation completed	84
14	Qualification by data from other applications - evaluation completed	54
15	Qualification as part of higher assembly - evaluation completed	24
16	Qualification by test - qualification or approval incomplete	42
17	Qualification by similarity - qualification or approval incomplete	32
18	Qualification by similarity and test - qualification or approval incomplete	72
19	Approval by evaluation - approval incomplete	62
20	Qualification by test and data from other applications - qualification or approval incomplete	82
21	Qualification or part of higher assembly - qualification or approval incomplete	22
22	Qualification by data from other applications - qualification or approval incomplete	52
23	Qualification by test - in test	48
24	Qualification by similarity - in evaluation	38
25	Qualification by similarity and test - in test or evaluation	78
26	Qualification by test and data from other applications - in test or evaluation	88
27	Qualification by data from other applications - in evaluation	58
28	Qualification as part of higher assembly - in test or evaluation	28
29	Qualification by test - test not begun	43
30	Qualification by similarity - evaluation not begun	33

At the direction of the PCTR Program Manager, the Engineering organization and the Manufacturing and Procurement Groups conduct a study of the hardware configuration and submit a recommended Make or Buy List to the Make or Buy Board for approval (see Figure 4-14). Certain products fall outside of Northrop's capability and are immediately classified as "buy." These include such items as: communications equipment, elements of the data subsystem such as commutators, etc. Make items may be classified as "buy" even though Northrop may have an existing capability, due to excess workloads prevalent during the time span of the PCTR Program. To ascertain these loads, the Manufacturing organization contacts the affected divisions and determines their planned loads for the time span required. Work so transferred to another division of the Company is handled on an Interdivisional Work Order (IWO). Such effort is negotiated and an agreement reached on the hours and costs of the effort prior to initiation of same. By utilizing separate sales orders for the significant efforts to be accomplished by another division, actual cost versus agreed upon target cost can be monitored. Corporate procedures insure that fee is applied only once to total cost.

The Make or Buy List (Table 4-3) has been established for the PCTR Program as a result of actions described above.

After analyzing the hardware list of the items to be procured, it has been decided that no single item warrants definition as a subcontract item. All of the significant items fit the definition of High Value items described in 4.6.1.

4.6.2 PROCEDURES FOR SELECTION OF QUALIFIED PARTS AND COMPONENTS

This section establishes criteria by which parts, materials, and components are judged as suitable for utilization on the PCTR Program. The spare application requirements of the PCTR dictate that:

a. Selection criteria must be established commensurate with each end item use.

b. Flight application parts and materials must be space-qualified at the part level to reduce program risks.

c. Flight application components may be qualified at the subsystem level to reduce program cost when adequate justification can be provided.

4.6.3 MAKE OR BUY LIST

Table 4-3 shows the Make or Buy List. This list is established based on the policy and procedure described in sections 4.6.1 and 4.6.2.

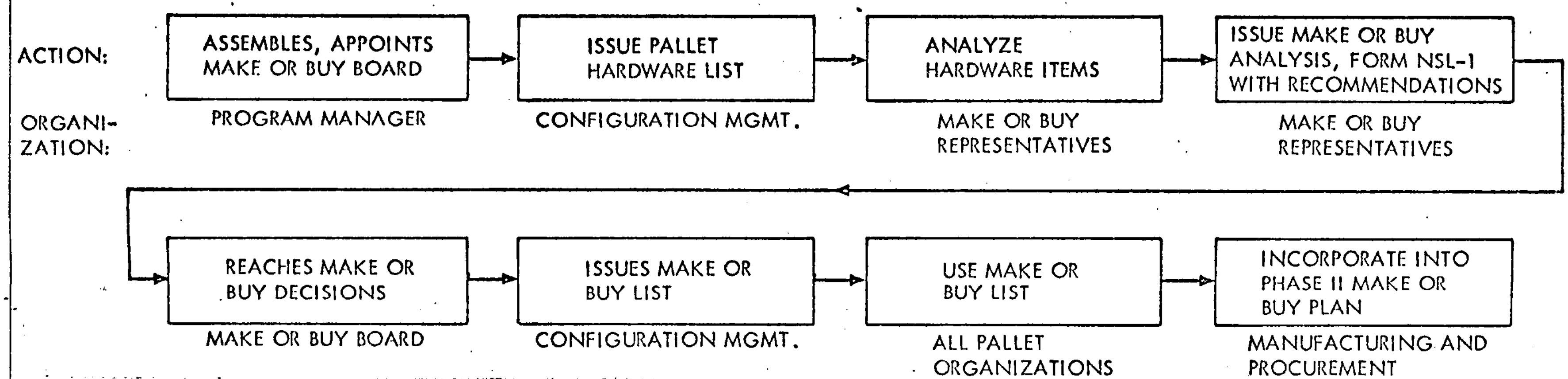


FIGURE 4-14 MAKE OR BUY STEPS

TABLE 4-3 MAKE OR BUY LIST

	Make or Buy	Quantity Per System	Total Quantity
Radiator Experiment Unit			
Space Radiator		1	4
PCTR	M	1	4
Simple Radiator	M	1	4
Module	M	1	4
Insulation	B	1	4
Sink Radiator		1	4
PCTR	M	1	4
Module	M	1	4
LN2 System	B	1	4
Insulation	B	1	4
Structure	M	1	4
Heat Shield	M	1	4
Data Package	M	1	4
Observation Experiment Unit		1	4
Optics Subsystem	M/B	1	4
Illumination	M/B	1	4
Cell Positioner	M	1	4
Camera	B	1	4
Cabinet	M	1	4
Electronics Case	M	1	4
Test Cells	M	6	36
Cell Storage (Ambient)	M	1	4
Cell Storage Cold	M/B	1	4
Support Subsystem		1	4
Data Subsystem			
Programmer	M/B	1	4
A/D Converter	M/B	1	4
Multiplexer - 12 Channel	M/B	1	4
Multiplexer - 8 Channel	M/B	1	4
Module Assembly-Signal Conditioning Amplifiers	M/B	1	4

TABLE 4-3 Continued

	Make or Buy	Quantity Per System	Total Quantity
Module Assembly Analog Gate	M/B	1	4
Module Assembly A/D Ladder	M/B	1	4
Module Assembly Heater Control	M/B	1	4
Module Assembly - Multiplexer Decoder	M/B	2	8
Radiator Exp. Electronic Assembly	M/B	1	4
Tape Recorder	B	1	4
Power & Control Subsystem			
Power Supply-Illuminator	M/B	1	4
Power Supply +24 Volts	M/B	1	4
Power Supply +12 Volts	M/B	1	4
Power Supply +10 Volts	M/B	1	4
Power Supply +4.5 Volts	M/B	1	4
Power Supply -12 Volts	M/B	1	4
Power Supply -6 Volts	M/B	1	4
Battery +28V, 1200 amp HRS	B	1	5
Battery -24V, 28 amp HRS	B	1	5
Controller-Observation Exp.	M/B	1	4
Wiring Interconnect	-	1	4
Control Panel	M/B	1	4
Cabling	M/B	1	4
Ground Support Equipment	-	-	-
Checkout Console	M/B	-	1
LN_2 Fill System	B	-	1
Battery Installation Equip.	B	-	1

NSL 67-205

QUALITY, RELIABILITY AND SAFETY PLAN

Section 5

CONTENTS

QUALITY, RELIABILITY AND SAFETY PLAN

ILLUSTRATIONS

5.0 QUALITY, RELIABILITY AND SAFETY PLAN

This plan describes the philosophy and methods for inspection, checkout and control of the PCTR Program end items to assure conformation to engineering requirements. It also describes how the PCTR mission reliability and crew safety will be achieved.

Section 5.1 of this plan describes the Quality Plan; Section 5.2 the Reliability Plan; and section 5.3 the Safety Plan.

5.1 Quality Control Plan

Northrop's Quality Control System is based on NASA NPC 200-2 and MIL-Q-9858A. The following sections describe how Northrop would comply with NPC 200-3 for the Phase Change Thermal Radiator (PCTR) Program.

5.1.1 ORGANIZATION AND MANAGEMENT

The Quality Control function for Northrop Systems Laboratories is placed high in the organizational structure to assure objective evaluation of quality matters. The Quality Assurance Section reports directly to the Director, Operations Section with delegated responsibility for assuring that end items are of acceptable quality and in compliance with engineering drawings, specifications and customer requirements.

The Quality Control function encompasses the planning, control, evaluation and reporting of all quality aspects of the program from the development phase through fabrication, processing, storage, and delivery.

Continued achievement of design reliability is dependent upon strict control of all material and process characteristics which maintain the integrity of the design. Therefore, those activities related to product reliability are appropriately reflected in all the principal work elements of the Quality Control Program Plan.

The prime responsibility of Quality Control is to assure conformance of equipment to drawings and specifications through performance of continuous in-process verifications, tests, and end item final inspections. These inspections and tests are conducted in accordance with plans and procedures developed through the coordinated efforts of Manufacturing Engineering, Quality Control, and Operations.

The Control personnel assigned to the programs answer organizationally to the Director, Operations Section. Services of other segments of Northrop Nortronics Quality Control Department are available on a contingency basis if the need arises. Overall responsibility for implementing and managing Quality Assurance rests solely with the Director, Operations Section, who answers directly to the Nortronics-NSL Vice President and Manager.

5.1.2 SUPPLIER CONTROL

Quality and delivery capabilities of Northrop suppliers are signficant considerations in the selection of procurement sources. This Section identifies and describes the following supplier control tasks: a) Supplier Selection, b) Northrop Source Inspection, c) Supplier Data and Documentation, and e) Quality Control Requirements for Suppliers.

5.1.2.1 Supplier Selection

Quality Control participates in the pre-award evaluation and selection of procurement sources. Formal approval of suppliers is based on satisfaction of one or both of the following conditions:

a. The supplier shall have a previous and continuous quality history of supplying high quality articles of the type being procured. Performance histories and objective quality evidence obtained at receiving inspection are used to evaluate prospective suppliers.

b. If no previous quality history is available, a survey of the supplier's facilities and quality control systems is performed to assure that he is qualified to supply articles which meet the quality requirements of the purchase order.

Northrop's "Implementation Manual for Quality Source Evaluation" provides a uniform set of instructions for implementing Northrop quality control documents, and the "Northrop Key Plan" for procurement source quality at supplier facilities located in the Eastern United States and

Eastern Provinces of Canada. (See Figure 1)

Northrop's Key Plan source control places quality control representatives empowered to serve the needs of all divisions within the Corporations, in all strategic supplier centers. These representatives have extensive experience in the control of procurement source quality. The Key Plan was authorized on September 9, 1963, with the issuance of Corporate Executive Bulletin 36, "Control of Procurement Source Quality - Key Plan."

All segments of the Northrop Corporation make use of the quality control services (Key Plan supplier surveys, source surveillance, liaison activities) available from the Eastern Quality Control Office located at the Nortronics Division in Norwood, Massachusetts. The location of Quality Control Field Representatives and the span of coverage provided by the Eastern Quality Control Office are shown in Figure 1.

5.1.2.2 Northrop Source Inspection

For selected items of equipment, Northrop performs in -process surveillance and final acceptance test verification at the supplier's facility. This precludes the necessity of providing duplicate test equipment for incoming inspection purposes. Acceptance test data and qualification status are checked prior to shipment of the equipment to Northrop. A "Quality Control Action Request," Form C71, is used to notify the Eastern Quality Control office that source surveillance or final inspection is required (see Figure 2 for sample of Form C71). Applicable specifications, drawingsand special instructions are submitted with the request. Necessary information is forwarded to the Eastern Quality Control office in sufficient time to enable the Quality Control Field Representative to familiarize himself with equipment specifications and quality requirements.

5.1.2.3 Supplier Data and Documentation

Objective quality evidence is required of suppliers to demonstrate compliance with equipment qualification requirements, acceptance test

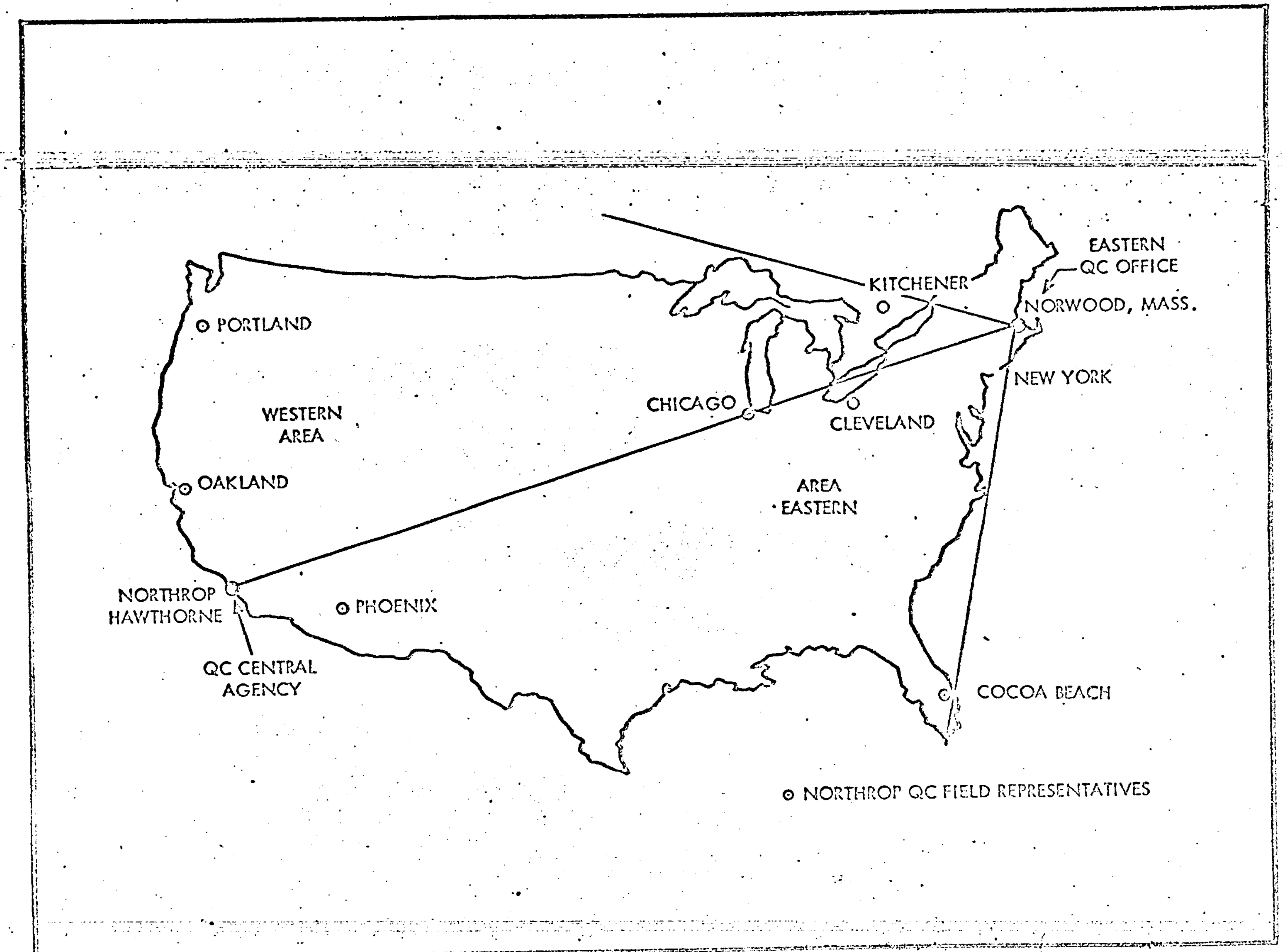


FIGURE 5-1 NORTHROP KEY PLAN COVERAGE

QUALITY CONTROL ACTION REQUEST

FORM C-71 (0-65).

NORTHROP KEY PLAN

No. 00011

1. SUPPLIER NAME	2. P.O. NO.	3. PART NAME	4. PART NO.
Jones Supply Corp.	6-03498	Battery	127-59003

5. SUPPLIER ADDRESS	6. REQUESTING DIVISION	7. PHONE	8. DATE
Joplin, Missouri	Northrop Space Laboratories	(805)258-2111	3/28/66

9. REQUESTER	10. ORGN. NO.	11. EXT.	12. BUYER	13. GROUP	14. ORGN. NO.	15. EXT.
R. Cooper	2660	2771	C. Dunlap	A-6	6510	2797

QUALITY CONTROL ACTION REQUESTED

16. ☐ KEY QUALITY SYSTEM SURVEILLANCE Q.C. 500 LEVEL ☐ 1 ☐ 2 ☐ 3 ☐ 4 SPECIFY FREQUENCY

17. ☐ SPECIAL QUALITY AUDIT REQUIREMENTS

- ☐ Procurement Control
- ☐ In-Process Inspection
- ☐ Configuration Control
- ☐ Process Control
- ☐ Quality Records
- ☐ Drawing and Spec. Control
- ☐ Materials Storage and Handling
- ☐ Nonconforming Material
- ☐ Corrective Action System
- ☐ Other (Specify) __________

18. ☒ SOURCE INSPECTION REQUIREMENTS

- ☐ Inspection Check List Supplied
- ☐ In-Process Inspection ☐ 100% ☐ Sample (To____AQL) ☐ Surveillance
- ☒ Final Assembly Inspection ☐ 100% ☐ Sample (To____AQL) ☐ Surveillance
- ☒ Functional Test Inspection ☐ 100% ☐ Sample (To____AQL) ☐ Surveillance
- ☐ Functional Test Inspection Critical Characteristics Only - Specify in Item 20
- ☐ First Article Inspection
- ☒ Data Submittal Requirements. Specify in Item 20
- ☐ Process Control
- ☒ Shipping Inspection
- ☐ Other (Specify) __________

19. ☐ CORRECTIVE ACTION INVESTIGATION DEFINE PROBLEM IN ITEM 20

20. SPECIAL INSTRUCTIONS

1. Qualification status summary to be checked prior to shipment; summary and qualification test report number to be shipped with equipment.
2. Actual readings of final acceptance test, failure reports to be submitted.
3. Verify electrical performance tests; leak test; terminal impedance; insulation test.
4. Verify preservation and packaging for shipment.

21. APPLICABLE TECHNICAL DATA

(LIST AND USE "(S)" TO IDENTIFY DATA SUPPLIED WITH THIS REQUEST)

☒ ENGINEERING DRAWINGS ☒ TEST PROCEDURES ☐ PROCESS SPECIFICATION ☐ OTHER

Dwg. 127-59003

ITWO 170653 "Acceptance Test Procedure"

22. KEY CONTROL OFFICE SUPERVISOR	23. DATE	24. KEY CONTROL QUALITY REPRESENTATIVE	25. DATE

FIGURE 5-2 QUALITY CONTROL ACTION REQUEST

procedure, and procurement specification requirements. Specific quality assurance requirements are included in procurement specifications for functional items categorized as critical components and major assemblies.

5.1.2.4 Quality Control Requirements for Suppliers

Northrop Quality Control Specification No. 500-1 is established as the basis for specifying quality control system requirements for suppliers and for classifying sources with respect to quality control capability and performance. A unique feature of this document, which is used throughout the Northrop Corporation, is the "Applicability Index," which provides flexibility of application. Individual levels of compliance to Quality Control Specification No. 500-1 are specified for buy items dependent upon the critical nature of complexity of the material or equipment. For cross-reference purposes, paragraphs of this specification are identified with the appropriate applicability index level number.

A representative from Quality Control reviews the content of purchase orders for major components and critical materials prior to release to verify that explicit quality assurance requirements are included. The objective of purchase order screening is to assure transmittal of complete and precise details of Northrop requirements to the supplier.

5.1.3 INITIAL QUALITY PLANNING

Quality Control is responsible for establishing the quality assurance provisions for manufacturing processes, determining that quality objectives and requirements have been defined sufficiently to allow adequate quality planning, and analyzing quality data to measure effectiveness of the quality control system.

This function is characterized by intensive "upstream" effort that establishes an integrated program for the control of product quality. It is the activity that ties together and directs the planning, control, evaluation, and reporting, of all the quality aspects of fabrication, installation, and checkout tasks.

Items evaluated during design reviews conducted on an incremental basis include materials applications, behavior, methods of joining, finish protections, cleanliness requirements, and fabrication techniques for subsequent process control consideration. Data compiled during drawing and specification reviews is used by Quality Control for the timely and effective planning of inspection verification points in tool fabrication orders, and Manufacturing Assembly and Acceptance Sheets.

5.1.3.1 Test Procedure Review

Quality Control participates with Test, Checkout, and Operations in preparing acceptance test procedures to identify inspection measuring and test equipment requirements, and to evaluate procedures for clarity and completeness of acceptance criteria. Inspection and test procedures contain data which:

a. Define test objectives and provide specific instructions for obtaining test data,

b. Identify measuring and test equipment to be used (range, accuracy, and type),

c. Specify exact method of measuring, and

d. Specify acceptance criteria (performance parameters, input levels and tolerance limits).

5.1.3.2 Process Controls

Control of materials and processes is an important element of the quality program. To implement this function successfully, Quality Control establishes and maintains control activities to assure that materials, equipment, and processes conform to Northrop Process Specifications. Existing process control plans and procedures for chemical, metallurgical and nondestructive test methods are applicable. Additional procedures are developed where necessary, for processes peculiar to the program.

Quality Control verifies certification of all personnel performing work or special processes that require certification by Northrop or customer specifications. This certification program includes manufacturing processes such as hand soldering, welding, electrical-electronic fabrication, installation of special fasteners, sealing, etc. Northrop currently has Category II - Instructor/Examiner capabilities for hand soldering of electrical connections (NASA NPC 200-4) and fabrication of welded electronic modules (MSFC-STD-271). Training requirements are outlined in the Nortronics Product Integrity Manual, Procedure PS-3.1, and Norair S.P.F. 9-1.5.

The adequacy of in-plant processes during manufacture is assured through periodic physical and chemical tests on materials and the continuing evaluation of equipment affecting those processes. The facilities of suppliers performing special processes (heat treat, plating, etc.,) are surveyed and qualified to establish compliance with applicable process specifications and requirements. Maximum use is made of Northrop's List of Approved Process Suppliers.

5.1.3.3 Quality Planning

Prior to release of Manufacturing Assembly and Acceptance Sheet (MAAS) Masters for reproduction and distribution, Quality Control codes each job number in the Buy-Off code column of the MAAS as indicated below.

a. Q - In-Process Quality Control Acceptance

b. C - Fabrication and assembly responsibility

c. E/I - End Item Acceptance

d. A - Customer Acceptance

e. X - For fabrication and assembly information only (does not require inspection)

These manufacturing plans reflect precise operational instructions, specification references, sequence of assembly and tests, and test equipment requirements.

A Quality Control Representative serves on the Change Control Board to evaluate engineering changes and to determine their impact on the quality plan. Follow-up is taken to assure incorporation of approved changes in the Manufacturing Plan at the designated effectivity point. Verification that the change has been accomplished on the hardware is established through an audit of the completed inspection records.

5.1.3.4 Failure Reporting and Corrective Action

Northrop's Failure Reporting and Corrective Action system provides effective notification, distribution, analysis, and corrective action of all reported malfunctions and failures. This system satisfies failure reporting requirements for assuring conformance of equipment with design criteria and for effective and timely correction of nonconformances. It also provides assignment of organizational responsibility for implementation to preventive action to preclude recurrence of the malfunction or deficiency. This assignment of responsibility applies to line organizational such as Engineering, Manufacturing, Test, Operations, and Quality Control. Corrective action requests involving purchased equipment are processed through the Procurement group for transmittal to the responsible supplier. Whenever practicable, supplier representatives assist in the investigation and analysis of failed equipment purchased off-site. Inspection Rejection Report, Form AMS 1806, is used for failure reporting.

Failure reporting is initiated during qualification test programs. Test data accumulated and analyzed during these tests are used to provide basic data for reliability assessment analysis.

The IRR identifies the failed equipment and provides failure characteristics, symptom data, and a description of the conditions under which the failure occurred. The system functions through the coordinated efforts of the cognizant engineer (individual responsible for analysis of functional failures reported), Reliability Engineering, and the Quality Control Representative. This team effort assures that necessary corrective action is taken, such as the performance of failure cause analysis, and assures the initiation of design or test procedure change actions. The Cognizant Engineer's Group Chief, by his sign-off of completed IRR forms, is made aware of problems or failures occurring on equipment under his control.

On smaller programs which do not involve the quantities of hardware and documentation associated with a full-scale production program, the failure reporting and corrective action system paper flow is not automated. The system provides failure data required to support the failure summary reporting requirements of NPC 250-1 and provides for accumulation of basic data for reliability assessement analyses. Continuing follow-up action is taken to assure the adequacy of changes made to correct identified failure causes.

5.1.3.5 Quality Inspection

Quality Control is responsible for performing specific inspections and test verifications to assure that only materials and equipment meeting established specifications are accepted. This function includes in-process and final inspections in accordance with work instructions prepared by Manufacturing Engineering and approved by Quality Control. Inspection personnel receive technical support from the cognizant Quality Control Engineer for help in solving quality problems.

5.1.4 INCOMING INSPECTION

All incoming materials are inspected by Receiving Inspection to determine conformance with drawings and specification requirements indicated on the purchase order. Incoming inspection includes visual, dimensional, functional, physical, chemical, and nondestructive testing. Completed Receiving Reports provide a permanent record of each lot of material by purchase order number, supplier, date received, lot size, and test reports. First article parts receive a detailed review to determine specification conformance. Discrepancies recorded during first article inspection are fed back to the supplier and the Engineering Design Section. Follow-up action is maintained with the supplier to assure that these discrepancies are recorded.

Northrop source inspection at supplier's facilities is planned for critical components of some programs. This precludes the necessity of providing duplicate test equipment for receiving functional testing at Northrop. Space qualified parts and components are purchased from approved sources.

Raw materials (metal, wire, solder, potting and coating compounds, etc.) for the PCTR will be checked during Receiving Inspection for conformance to applicable specifications. A physical and chemical analysis report is required for all metals used on deliverable hardware. Time-sensitive materials such as encapsulants, potting and conformal coatings will have a tag or label attached which bears a rubber stamp impression reflecting material name, lot number and storage life expiration date. All incoming raw stock and materials on this program will be delivered direct to the using organization upon acceptance by Receiving Inspection and stored until used. Regularly scheduled inspection of the manufacturing areas are performed by Quality Control to verify proper storage and handling until the materials are used.

A first article and tool proving inspection is conducted on the first release of detail parts to assure adequacy of tools, manufacturing plan, and quality control requirements.

Inspection records and parts status are maintained during all stages of fabrication. All parts are stamped or tagged at the last inspection routing before stocking to assure identification with the shop traveler which is retained as a fabrication and inspection record. Discrepancy recording and data feedback is maintained in fabrication areas to provide a continuous measure and historical record of area performance.

Northrop's "Inspection Discrepancy Report" form is used to record nonconformances detected during in-process fabrication.

Assembly and installation operations are inspected to specifications indicated on Production Orders, Nortronics Form 46A, prepared by Manufacturing Engineering and approved by Quality Planning. Progressive inspection items such as precision assembly, close tolerance and critical hole checks, special torque requirements, and functional checks. End-station final inspections include a thorough check of the assembly for quality, configuration accountability, and conformance to workmanship standards, drawings, and specifications.

5.1.4.1 Sampling Inspection

NSL does not expect to use sampling inspection procedures. All items will be 100% inspected; however, if at a later date the use of sampling plans appear to be advantageous to the program, they may be instituted. All sampling inspections will be performed to meet the requirements of MIL Standard 105. Approvals to use sampling plans will be obtained from the Cognizant Government and customer agencies prior to implementation.

5.1.4.2 Government Furnished Equipment (GFE)

GFE, if required for the PCPR Program, will be inspected, and if necessary tested, upon receipt at Northrop. GFE will be segregated and stored in a locked and bonded area. Periodic inspections are made to assure storage conditions are adequate to guard against possible deterioration or damage during storage. Damaged or defective GFE will be reported on Northrop Form AMS 1806, Inspection Rejection Report, and submitted to the Material Review Board for disposition.

5.1.4.3 Government Inspection

Government inspection is conducted by a designated Government inspection agency. Mandatory inspection points are established by the Customer's cognizant

Quality Assurance Representatives. The buy-off code column of the Time Limited Production/Rework Order indicates Customer inspection verification points. Northrop work operations do not continue beyond these check points until the cognizant Government agency personnel have completed their inspection or have completed their inspection or have waived the requirement.

Government Source Inspection, when deemed necessary,will be requested utilizing form 27-669, "Government Source Inspection Request", to obtain approval from the cognizant Government Agency. A separate request is required for each Purchase Requisition. If approved the requirement for Government Source Inspection will be indicated on the Purchase Requisition in accordance with Section 3.2 of NPC 200-3, and Northrop Standard Practice Memorandum D-2.

5.1.4.4 <u>Calibration and Standards</u>

Northrop Prime Standards of Measurement encompassing basic references to time, mass and length are under the operation and surveillance of the Quality Control Organization, and are maintained in accordance with the requirements of MIL-C-45662A "Calibration System Requirements". All units of measure utilized in the manufacturing areas bear direct traceability to the National Bureau of Standards or an authorized agency having certified traceability. Each unit of equipment bears a Quality Control decal which indicates calibration status and due date for recalibration. Prior to calibration expiration date, equipment recall notices are sent to the using organizations.

Two associated areas operate in conjunction with Standards Laboratory and under the same administrative responsibility: (a) Maintenance and Repair Laboratory of Precision Measuring and Test Equipment (PMTE); and (b) Operations Center, a centralized equipment and records operation forming the nucleus for the laboratories. Historical data and accountability of all PMTE is recorded and maintained through electronic data processing (IBM) which is capable of highlighting repeated malfunctions, parts costs, and repair/calibration hours along with other pertinent information.

The Standards and Calibration Laboratory maintains historical records of measuring and testing equipment relative to the number of calibrations, repairs replacement parts, cost, etc., performed in the Calibration Laboratory.

Frequency of equipment recall is scheduled by the Standards and Calibration Laboratory in coordination with the using organization, and is established by analysis of equipment accuracy, stability, and degree of usage. Frequency of recall is based on usage days or time units, as applicable.

5.1.4.5 Functional Tests

All functional tests of deliverable hardware will be witnessed 100% by Quality Control personnel. Detailed test and inspection procedures are available prior to initiation of tests and inspections. Actual readings obtained during end item acceptance tests are documented in the Test Procedure Data Sheets and are available for review by the cognizant customer representative.

After end item test and inspection, the occurrence of any unauthorized modifications, repair, disassembly, or damage, resulting from mishandling will necessitate reinspection and retest to the extent deemed necessary by Quality Control.

5.1.4.6 Nonconforming Materials

Nonconforming materials will be withheld from the fabrication process and submitted to authorized MRB personnel for review and disposition. The Materials Review Board will consist of members from NSL engineering, quality control and the cognizant customer representative. Nonconformances that adversely affect safety, performance, reliability or weight will be submitted to the customer for approval. All MRB dispositions will be documented on Form 1806 Inspection Rejection Report.

5.1.4.7 Quality Data and Documentation

Quality data and documentation maintained by Northrop includes off-site source, receiving, in-process, and final inspection records required to demonstrate control of equipment quality during fabrication, installation and checkout operations. Meaningful management information such as quality tends, spoilage reports and quality problems are maintained for Customer on-site review.

Completed Inspection records are audited by Quality Control for conpleteness prior to filing. These records include Limited Production/Reword Orders, Shortage Sheets, Drawing Change and E.O. Lists, Removal Records, Inspection Pickup (Squawk) Sheets and Equipment History Logs. Configuration accountability of each end item is maintained and validated by Quality Control through this audit of completed inspection records.

Equipment History Logs, NSL Form 94, will be maintained for all major functional elements of deliverable equipment. This provides a record of all inspections and tests, as well as recording malfunctions and failures of the affected hardware.

5.1.4.8 Package and Shipping Inspection

All shipments of equipment and loose items are inspected for proper preservation, general condition, and compliance with packaging requirements to preclude damage or deterioration during shipment. Shipping documentation prescribes the method of processing and packaging. Inspection verification is performed after each operation such as cleaning, processing, intermediate packaging, labeling and crating. Shipping documents are reviewed for completeness of entries for delivery location, shipping authority, equipment identification, serial numbers and Customer approval, when applicable.

Exterior packaging is inspected for means of indicating critical environment within the package or container, such as moisture content, temperature, and pressure. When handling of critical components or maintenance of specific internal environment is necessary, special instructions are included in the packaging and on the exterior package.

5.2 Reliability Plan

5.2.1 INTRODUCTION

5.2.1.1 Scope and Objective

This document describes the reliability activity designed to give maximum confidence in the PTCR. It follows the intent and is consistent with those elements of the NASA Reliability Publication NPC 250-1, Reliability Program Provisions for Space System Contractors, dated July 1963, considered essential to the PTCR Program. Exceptions to NPC 250-1 reflected in the plan involve Reliability Program Control, Indoctrination and Training, Supplier Control, Maintainability, Standardization, Parts and Materials Program, Reliability Assessment, Weekly Progress Reports, and Program Control Reports. These exceptions are tabulated in subsection 5.1.5.

The objective of this document is to indicate the authority of the Reliability organization, the direction of the Reliability Program, and the substance of the Reliability tasks.

5.2.1.2 Organization, Management and Facilities

Reliability personnel assigned to the PCTR Program are responsible directly to the Program Manager. They are also linked to other segments of Northrop's Reliability organization on whom they may call for centralized services to support the program as required. Some of these services include additional reliability engineers to supplement peak manpower needs; PRINCE and FARADA records, IDEP microfilm viewing and storage facilities; the Reliability and Quality Control Laboratory; internal Failure Analysis records; part, material, and process specification standards; and electronic piece parts screening and conditioning equipment for culling infant mortality parts and stabilizing device parameters. (This screening equipment is described in more detail in the paragraphs below. The organizational structure for the Reliability effort is shown in Figure 5-3.

5.2.1.3 Applicability

This document describes a Reliability program for spacecraft flight hardware, GSE, the Laboratory Test Model, and spares. Some of the Reliability tasks are common, others are not.

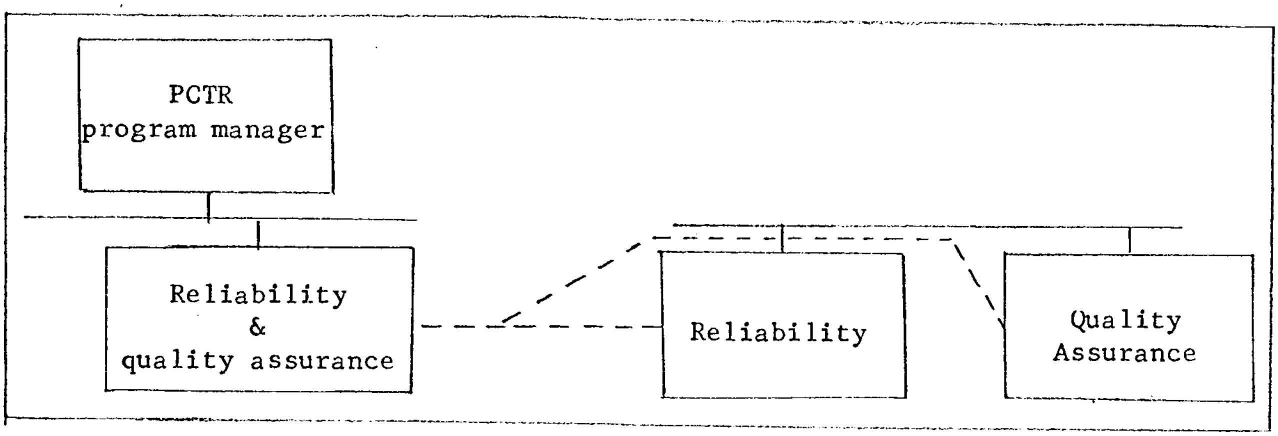


FIGURE 5-3 ORGANIZATION CHART

5.2.2 RELIABILITY PROGRAM GUIDELINES AND CONCEPTS

5.2.2.1 Guidelines

The reliability effort described in this plan is directed towards providing an orderly and organized attack on all areas of probable failure during the mission.

5.2.2.1.1 Assumptions

a. The mission consists of launch into orbit, normal operation of all equipment for twenty hours and recovery of data and samples.

b. While development of some items is anticipated, no state-of-the-art advancement is anticipated.

c. Maximum of two year shelf life (batteries and observation test cells excluded) check out prior to the mission. Batteries, test cells and LN_2 will be supplied prior to launch.

d. Limited reliability tests supported by hardware analysis can reveal failure modes without the necessity of extensive testing of statistically significant quantities.

5.2.2.1.2 Approach

a. The ability of novel or previously undemonstrated designs to meet performance requirements for the required life will be verified.

b. The suitability of hardware selected from other spacecraft applications for this Program will be verified.

c. Interactions between subassemblies will be subjected to special analysis for unexpected hazards.

5.2.2.2 Applicable Reliability Concepts

a. Mission essential functions may be initiated by at least two independent means.

b. Preferred designs and parts having established reliable space-application performance data will be selected, if possible.

c. No single electronic failure shall result in subsystem failure.

d. Parts will be derated to allow ample performance margins between capability and use.

e. The effect of external environmental stresses on the inherent properties of items will be allowed for.

f. Maximum tolerances without failure or degradation will be the practice.

g. Fault isolation or fail-safe mode will be inherent design wherever possible.

h. Worst-case design techniques will be employed.

i. Failure modes will be minimized by search, discovery, and redesign.

j. Every attempt will be made to select high reliability standard parts and components previously qualified for similar space applications, while recognizing that parts are not perfect and every subsystem design that accommodates an unanticipated failure without impairment of subsystem function is a preferred design.

k. Although reliability is frequently a reciprocal of complexity and quantity of items, there are exceptions where a more complicated design may be more reliable than a simplified one.

l. The most careful screening of parts and production processes cannot eliminate all flaws. Element redundancy will employ identical elements in parallel to compensate for random failure during normal life.

m. Functional redundancy may be used to provide two parallel independent paths composed of physically different functionally identical equipment.

n. Degradation redundancy consisting of excess capacity will be used to allow for reduced or degraded performance.

o. If an item is critical to survival, triple redundancy is desirable.

5.2.3 Reliability Tasks

The reliability tasks which implement reaching the objectives of the Reliability Plan are shown in the Reliability Activity Diagram, Figure 5-4.

The reliability activities will follow three fundamentally different approaches, starting from three different viewpoints, and all focused on the target of identifying potential failure. The three general tasks which implement the above approaches consist of: a thorough review and analysis of the design as discussed in 5.2.3.1, mathematical analysis as discussed in 5.2.3.2, and a series of reliability tests as discussed in 5.2.3.3.

5.2.3.1 Design Analysis Tasks

5.2.3.1.1 Informal Design Review

Informal design review will occur on a continuing basis during the design and manufacturing phases. Its use permits reliability inputs to the design and provides some of the information required from design for reliability analyses. Informal design review concerns itself with selection of the best materials, mechanisms that work with monotonous reliability, operational loads and transient stress, interface coordination, maintainability, and any other features that will improve a design's performance or reliability.

5.2.3.1.2 Formal Design Reviews

In accordance with Section 3.6, "Design Review Program", of NPC 250-1 and Exhibit XIV, "Formal Configuration Management Reviews, Inspections and

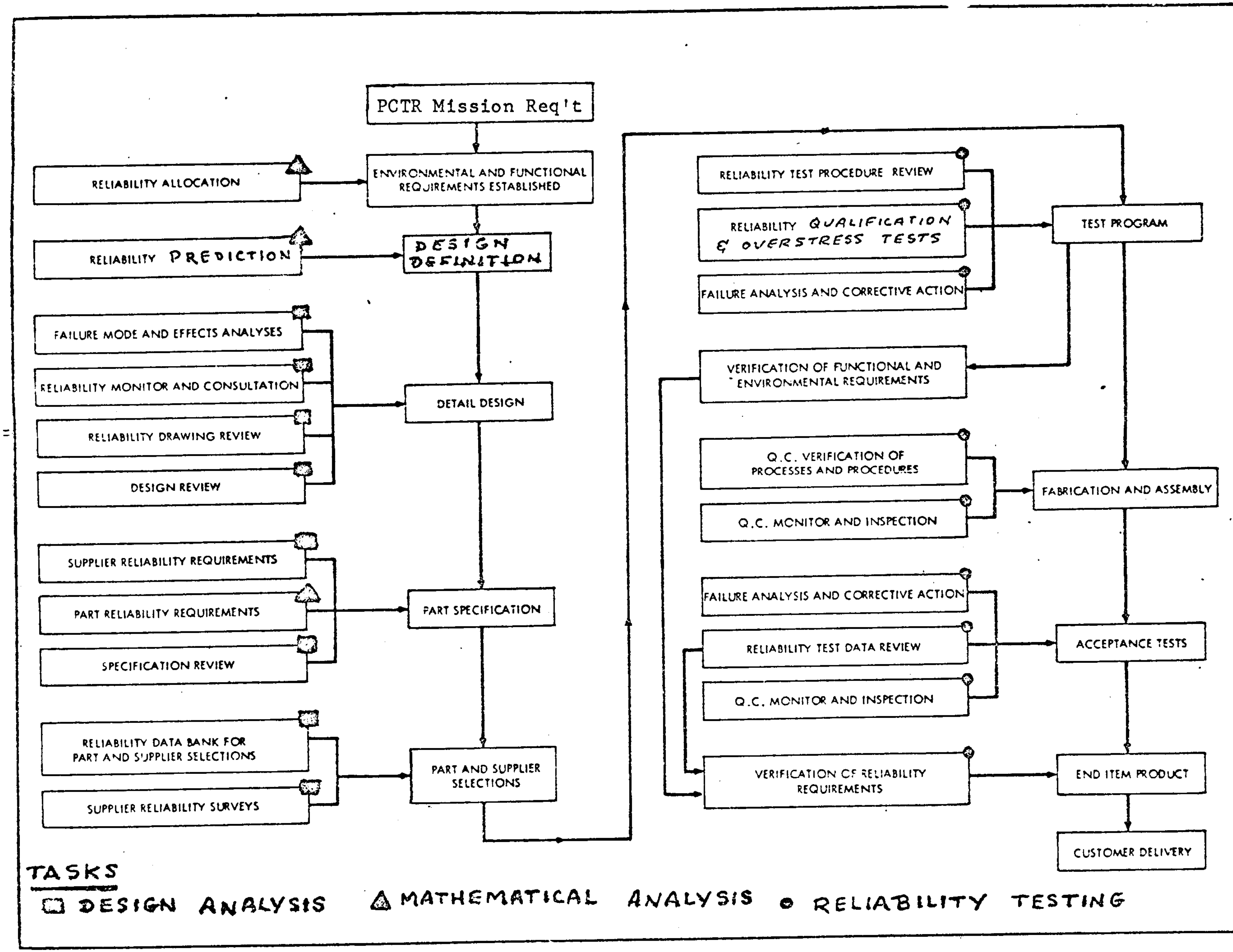


FIGURE 5-4 RELIABILITY ACTIVITIES

5.2.3.1.2 (con't)

Demonstrations," of NPC 500-1, formal design reviews will be held on the PCTR which consists of the equipment shown on Figure 5-5 and on GSE.

Formal design review meetings will be conducted by the Northrop program personnel for the NASA personnel. The four design reviews to be conducted are: Preliminary Design Review (PDR), Critical Design Review (CDR), First Article Configuration Inspection (FACI), and Flight Readiness Review. Scheduling, procedures, responsibilities, and substance of each type of review will be as described in Exhibit XIV of NPC 500-1.

Equipment characteristics will be reviewed for interface compatibility; performance capability; drift, stability, and wear; alternate design concepts; derating for environmental stresses; materials selection; and potential failures. For example, prior to the PDR and CDR, design engineers presenting designs for review will identify, and be prepared to discuss, possible failure modes in their designs, consequences of the failure, its ability to produce failure or degradation on interfacing equipment, and which characteristics are most critical during manufacturing and flight. These reviews will be scheduled at time periods agreed upon with the NASA.

5.2.3.1.3 Drawing and Specification Review

Northrop will comply with Section 3.2, "Design Specifications," of NPC 250-1. Procedurally, reliability and quality control will approve specifications and drawings prior to release. Quality Control will also review purchase requisitions and approve them prior to release to Procurement. The review of all documents will be made to ascertain adequate and valid statements

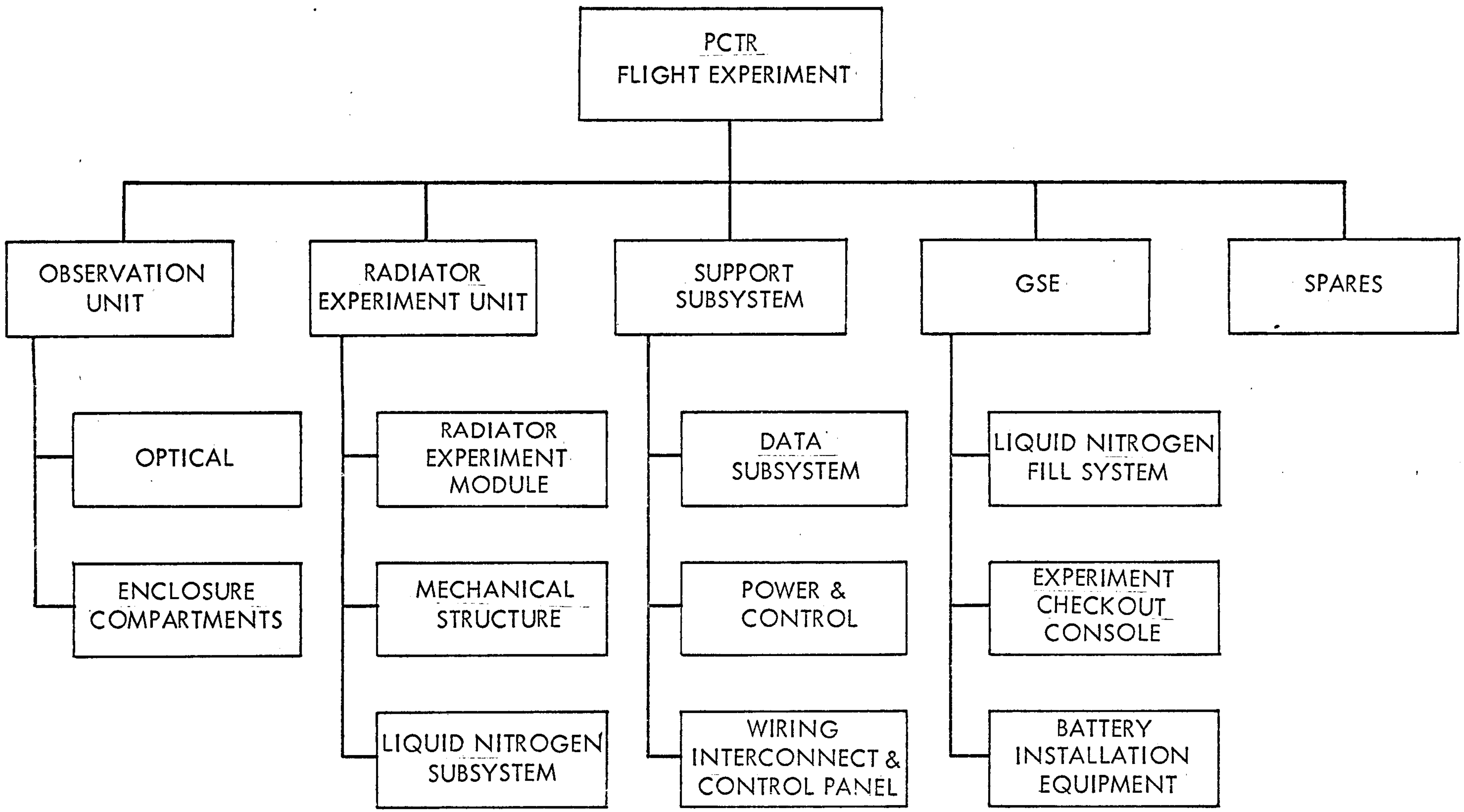


FIGURE 5-5 PCTR FLIGHT EXPERIMENT HARDWARE TREE

5.2.3.1.3 (con't)

of performance requirements, environmental profile requirements, pertinent test criteria, safety margins, derating factors, and apportioned reliability goals as these and similar data are applicable.

5.2.3.1.4 Failure Mode, Effect and Criticality Analysis (FMECA)

In accordance with Section 3.4, "Failure Mode, Effect, and Criticality Analysis", of NPC 250-1, Northrop will perform FMECA on all eight subsystems at the subsystem level (see Figure E3). In addition, a FMECA will be performed on all components which are not space qualified. These are the Observation Unit, Sink Radiator, Space Radiator, and Support System.

The analysis sheets may present the failures in tabular form or in tree form. A sample of each as used on other programs is shown in Figure 5-6 and 5-7. Format selected will be the one most clearly presenting the analysis of the subsystem or the component. The FMECA will reflect conceivable failures, anticipated causes, criticality or severity, probability of occurrence in very broad magnitudes, and recommended improvement techniques. Failure severity will be classified as mission failure, limited operation possible, correctible failure due to redundancy, limited initial failure with impending accelerated degradation, or negligible. The information obtained from the FMECA will be utilized in design reviews and test planning to direct attention to the defined failure modes.

Title NORMALLY OPEN/CLOSED EXPLOSIVE VALVE
Part No. P 46932 Next Ass'y No. ______

Prepared by:
Date:
Page:

CONCEIVABLE FAILURE	PROBABLE FAILURE CAUSE	FAILURE SEVERITY CLASS*	FAILURE FREQUENCY CLASS**	CAN FAILURE FEASIBLY BE AVOIDED?	CHANGE NECESSITATED	PROCEDURE NECESSITATED IF FAILURE DOES OCCUR
Premature or no-fire of primers	a. Open circuit in primer assembly	D_s	D_f	Yes	Improve wiring and/or potting.	In event of failure unit must be re-placed with new part
	b. Short circuit in primer assembly	D_s	D_f	Yes	Improve primer charge Q. C.	
	c. Excessive radio noise level	D_s	D_f	Yes	Improve confidence continuity checkout procedure and/or raido noise filtration.	
External or internal leakage of operating medium and causing premature depletion of N_2, N_2H_4 or N_2O_4 supply.	Faulty seal or primer installation					
	a. Leak could develop before launch	D_s	D_f	Yes	Improve sealing techniques and/or confidence leakage checkout procedure	a. In event of failure unit must be replaced in system with new part.
	b. Leak could develop after launch	C_s-A_s	D_f	Yes		b. Possible loss of midcourse correction capability--mission failure Failure severity dependent on magnitude of external leakage

• Failure Severity: A_s-Immediate mission failure
B_s-Correctable failure compensated by other system elements
C_s-Operation beyond spec limits not causing mission failure
D_s-Negligible

**Failure Frequency
A_f- 10%
B_f- 1.0%
C_f- 0.1%
D_f- 0.01 %

FIGURE 5-6 EXAMPLE OF RELIABILITY FAILURE MODE ANALYSIS

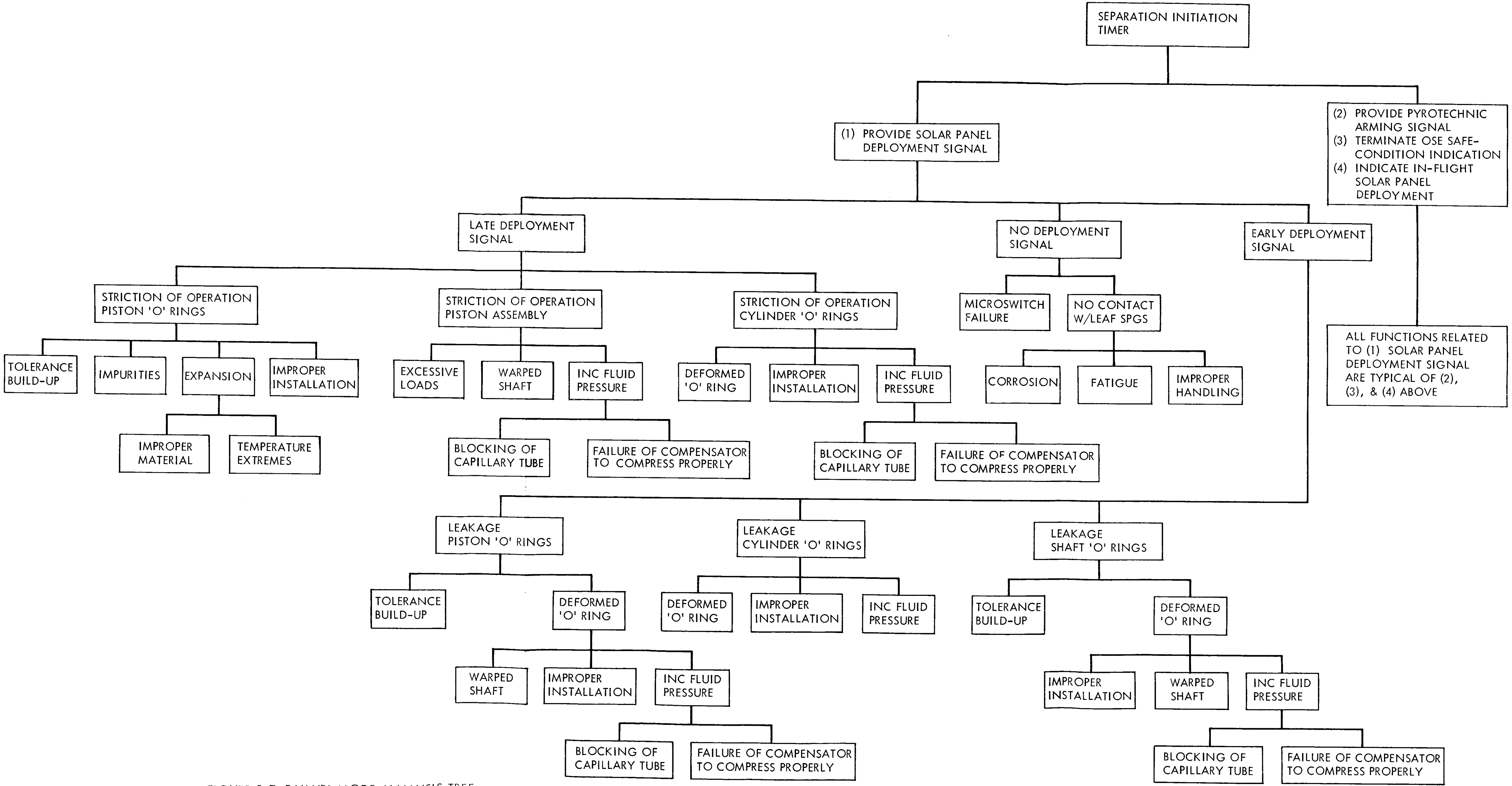


FIGURE 5-7 FAILURE MODE ANALYSIS TREE

5.2.3.1.5 Parts, Materials, and Components Selection

The parts and materials used will be selected from those qualified to an appropriate NASA or Military specification which matches the environments of the Master End Item Specification. All materials will be procured from Northrop's approved list of suppliers described in paragraph 2.4 of the Quality Plan, NSL 67-316. These materials will be required to meet the environmental and outgassing requirements in the Master End Item Specification.

Suppliers will be required to supply equipment performance data and proof of flight qualification. Where a need exists but no space qualified item is available, the equipment selected will be qualified during the Qualification Test Program. Any exceptions to the foregoing, such as unique instrumentation, will be qualified as agreed upon by both the NASA and Northrop when such item is selected.

Northrop will prepare and maintain a qualification status list showing the planned and completed qualification status of each part, component, subassembly, and higher level of assembly. The basis for any omission of qualification tests will be shown. Where qualification is based on similarity, reference is made to the pertinent test reports or data. The qualification status list and changes thereto will be submitted for approval at monthly intervals.

The procurement of non-preferred parts, materials, or non space-qualified components will be discouraged. However, when a suitable preferred item cannot be found, a non-preferred item will be used subject to both Design and Reliability approval. Approval will be based on need, vendor's accumulated data, similarity to qualified items, and the experience of the NASA/MSFC and other spacecraft contractors.

5.2.3.1.5 (cont'd)

Electronic parts in fabricated circuits will undergo electrical and thermal stress analysis. Derating procedures will be as described in MIL-Handbook 217A, Reliability Stress and Failure Rate Data for Electronic Equipment.

5.2.3.1.6 Reliability Indoctrination

Paragraph 2.5, "Reliability Indoctrination and Training," of NPC 250-1, requires an effective reliability training program. The quality and experience of the Northrop personnel obviates the necessity of a formal and extensive training program in the philosophy and discipline of reliability. Yet, continuous cognizance of the importance of the reliability aspects of the PCTR, etc., is essential to assure that these aspects are included in the design performance capability. This cognizance will be achieved by direct continuous contact and interchange of information between Reliability and Design engineers. Indoctrination and Reliability concepts will be achieved by continuous informal discussion in reviewing detailed designs as they evolve.

5.2.3.1.7 Data Bank

Reliability engineering will use the following data bank information where it contains applicable failure history.

a. PRINCE - Parts Reliability Information Center

b. APIC - Apollo Parts Information Center

c. IDEP - Interservice Data Exchange Program

d. FARADA - Failure Rate Data Program

5.2.3.1.8 Maintainability and Human Engineering

Reliability personnel will monitor design activities to assure that requirements of access for checkout, test inspection, and repair to PCTR equipment are met. The intent, as applicable, of Paragraph 5.3.5, "Maintainability and Elimination of Human Induced Failure," of NPC 250-1 will be met but no special instructional material or associated training is anticipated.

5.2.3.2 Reliability Testing

Several kinds of Reliability tests are required. In a sense, any tests conducted at any time during the PCTR Program are reliability tests because the results indicate equipment ability to perform to that point in time, or conversely, they discover a mode of failure. However, the tests discussed in this section are those designed to validate equipment quality to the desired level and then by further test to determine how close failure was and which modes would be the first to malfunction. This information can then be a basis for reliability evaluation and upgrading redesign.

5.2.3.2.1 Qualification Tests

The use of qualified equipment is the heart of any reliability program. Many of the items selected for the PCTR will be space qualified and a testing program will be conducted for the rest. The items which will require qualification and the test procedures to conduct such tests are described in the Test Plan.

5.2.3.2.2 Over-Stress Tests

Satisfactory completion of the Qualification test will qualify an otherwise unqualified item for the PCTR. This does not complete everything which it is practical to do in the search for failure modes.

5.2.3.2.2 (cont'd)

Upon completion of the Qualification test, hardware tests will be continued until failure occurs or some pre-established endurance point is passed.

The ability of the tested equipment to reach specified endurance points shall be satisfactory proof of full system conformance to contractual reliability requirements in accordance with Section 4, "Testing and Reliability Evaluation," of NPC 250-1. The items to be tested, test specifications, procedures, and reports for these over-stress tests are described in the Integrated Test Plan, NSL 67-314.

5.2.3.2.3 Failure Analysis and Corrective Action

Northrop's reporting is described in the Quality Program Plan. It is briefly mentioned here for the completeness of this document.

Northrop's Failure Analysis procedure meets the requirements of paragraph 3.7, "Failure Reporting and Correction," of NPC 250-1. Appendix B, "Quality Rejection Report," describes the originating failure report and the procedure for its use. Laboratory analysis of failures, when needed, will be conducted in the Reliability and Quality Control Laboratory, an air-conditioned facility equipped to conduct mechanical, electrical, and hydraulic evaluation tests.

5.2.3.2.4 Parts Screening and Conditioning

All electronic piece parts will be screened and conditioned (burned in) prior to installation in any component to cull the infant mortality parts and to stabilize the device parameters. All semiconductors will be x-rayed in two views. Detailed screening procedures will be created for each part or family

5.2.3.2.4 (cont'd)

of parts, and will specify tests to be conducted, measurement points, parameters to be measured, and allowable degradation during burn-in. Northrop's facilities include ovens and both manual and automatic curve tracing equipment for plotting semiconductor characteristics.

5.2.3.3 Subcontractor and Supplier Control

Northrop will comply with Paragraph 2.6, "Subcontractor and Supplier Control," of NPC 250-1. Any subcontractor for Support Systems will conduct the same program on his equipment which Northrop will follow on the PCTR as specified in this document. Other suppliers will have appropriate reliability requirements selected from this Program Plan included in their procurement directives. When possible, the screening and conditioning test requirements for electronic parts will be incorporated into procurement specifications. In those cases where testing will be done by the components or parts manufacturers, Northrop Quality Control will monitor the tests. Where the manufacturer is not equipped to perform screening tests, the parts will be tested at Northrop.

5.2.4 DOCUMENTATION AND REPORTS

5.2.4.1 Equipment Logs

Separate Equipment History Logs will be maintained for each major component subsystem, and the PCTR system.

5.2.4.2 Technical Reports

These following reports will be submitted to the NASA to satisfy the requirements of Section 5, "Documentation of Reliability Program", of NPC 250-1.

3.1.1 Design Review Action Reports

3.1.2 FMECA Studies

3.2.2 Math Model Prediction Studies

3.2.3 Apportionment Studies

3.3.4 Failure Analysis and Corrective Action Summaries

3.3.1 Qualification Testing Reports

3.3.2 Over-Stress Testing Reports

4.2 Monthly Progress Reports

Qualification Status List

5.3 Safety Plan

5.3.1 OBJECTIVE

The objective of the Safety Plan is to assure safety of the crew during launch operations and in flight by imposing appropriate requirements on all equipments and procedures employed in the PCTR Program.

5.3.2 METHODOLOGY

The Safety Plan objective is achieved by establishing responsibility in this area for carrying out the following tasks:

a. Identification of possible hazards

b. Imposing safety requirements on PCTR equipments

c. Restricting desired experimental and checkout procedures to those operations considered safe.

Like reliability, the nature of safety is subject to the laws of probability. No equipment can be considered 100 percent safe, but acceptably high standards of safety can be established. The technology of safety is not analytically developed to the same extent as reliability. Therefore, equally accurate predictions cannot be made and the estimates of safety are largely subjective, but based on related experience. There are, in many instances, close relationships between reliability of equipment and its safety. Therefore, it is important that Safety personnel work closely with Reliability personnel and the management. This type of interrelationship will be maintained as part of the Safety Plan.

5.3.3 SAFETY IN DESIGN

As the design configuration evolves, each interaction is reviewed for astronaut safety. Hazards are identified and memorandums are issued to the Design and Configuration Control organizations pointing out the hazard and, if possible, identifying more desirable design choices. No configuration design release is permitted until the safety design question is resolved.

5.3.4 SAFETY IN MANUFACTURING

The achievement of safe hardware in the manufacturing phase is largely a matter of quality assurance. For example, rough metallic edges can rip an astronaut's glove. By working closely with Quality Assurance, Safety can monitor those aspects of manufacturing which bear on astronaut safety, starting with Quality Assurance Specifications, and working through the various Quality Control functions.

5.3.5 SAFETY IN TEST AND OPERATIONS

The design will require ground checkout operations which offer no hazard to the astronauts and ground service personnel. In-flight safety will be achieved by not only the use of safe components, but the establishment and documentation of safe procedures and by prior training of the astronaut. EVA operations always involve a certain hazard. The retrieval of the Radiator Module is a relatively simple operation because of its light weight. Training in its removal and handling will add safety to the operation.

NSL 67-206

SECTION 6.0

TEST PLAN

TABLE OF CONTENTS

TEST PLAN

LIST OF ILLUSTRATIONS

SECTION 6.0

TEST PLAN

6.1 INTRODUCTION

6.1.1 Purpose

The purpose of this Test Plan is to define the requirements for the various types of testing pertinent to the acceptance and qualification of the Phase Change Thermal Radiator Flight Experiment.

6.1.2 Test Specimens

The tests specified within this document are to be performed to environmentally qualify each of the following units of the Phase Change Thermal Radiator Flight Experiment.

1. Observation Unit
2. Radiator Experiment Unit
3. Power Supply Unit

The Observation Unit, which will be stored and operated inside the Command Module (CM) consists of the following subassemblies:

1. Optical Subassembly
2. Electronic Compartment
3. Control Panel
4. Support Structure

The Radiator Experiment Unit, located in the Service Module, will consist of the following subassemblies:

1. Support Structure
2. Space Radiator
3. Sink Radiator
4. Data Package
5. Nitrogen Supply

The Power Supply Unit, also stored inside the Command Module, will consist of the following:

1. Batteries
2. Power Conversion Electronics
3. Wiring Interconnect
4. Support Structure

6.2 TEST OBJECTIVES

6.2.1 Acceptance

Acceptance testing will be performed on all flight hardware as a condition of acceptance. The objectives of acceptance testing will be:

a) Reveal defects in workmanship which cannot be readily determined by visual inspection or performance testing.
b) Detect and eliminate infant mortality type failures of components
c) Give assurance that the equipment can perform the mission for which it is intended.

6.2.2 Qualification

Qualification testing will be performed on each unit that comprises one system to demonstrate that the equipment can meet its design performance requirements when operated within its intended environment for its mission life cycle.

6.3 CRITERIA

6.3.1 Component Testing

Acceptance and qualification testing of purchased components will be performed by the component supplier whenever possible. Plans, procedures, and test reports prepared by suppliers will be reviewed for consistency with

Northrop and the NASA requirements. The NASA will retain the option to review and approve supplier plans and procedures.

6.3.2 Evaluation Testing

Each element of the Phase Change Thermal Radiator Flight Experiment will be evaluated for performance with respect to its application. Where confidence has been established in the performance of a part or component due to prior qualification, justifiable similarity of application, or rigorous analysis, further demonstration by testing will not be necessary. However, newly designed, developed or applied equipment will require physical demonstration and evaluation of suitability. Functional testing will be performed on each subsystem before integration into the system level.

6.4 TEST PROGRAM

6.4.1 Engineering Prototype Unit

An Engineering Prototype Unit will be constructed during the final design period to permit an evaluation of the system performance. The unit will be constructed in accordance with the operational configuration and will be used for:

a) Confirmation of design functional characteristics
b) Confirmation of resistance to environmental stresses
c) Availability of operating hardware to check out design modifications
d) Verification of mechanical and electrical interfaces
e) Checkout of ground support equipment
f) Detection of potential reliability problems
g) Accumulation of operating experience
h) Refinement of acceptance checkout techniques

i) Development of efficient prelaunch maintainability techniques

j) Availability of a training medium

k) Provide demonstrable confidence in initiating the qualification test program.

Final assembly and system level performance test will be preceded by individual tests of all subsystems.

6.4.2 Qualification Unit

A Qualification Unit will be constructed after the Engineering Prototype Unit and will be subjected to the following testing:

6.4.2.1 Visual Examination Test

Each assembly of the Qualification Unit will be examined for physical defects, damage or deterioration. Examinations will be performed after each environmental test; i.e., shock, vibration, acceleration, etc., to assure acceptability of specimen for the next test phase.

6.4.2.2 Performance Test

Prior to imposing any simulated environmental condition on the qualification unit assemblies, the specimens will be subjected to a complete functional performance test in accordance with an approved test procedure utilizing the Ground Support Equipment System Test Set.

6.4.2.3 Acceleration Test

Each of the three assemblies of the Qualification Unit will be subjected to an acceleration test. The test specimens will not be in operating mode during acceleration test, however, a complete functional test, in accordance with the NASA approved test procedure, will be performed subsequent to the acceleration test. Successful completion of this functional test will verify that the qualification unit meets the acceleration requirements shown in Figure 6-1.

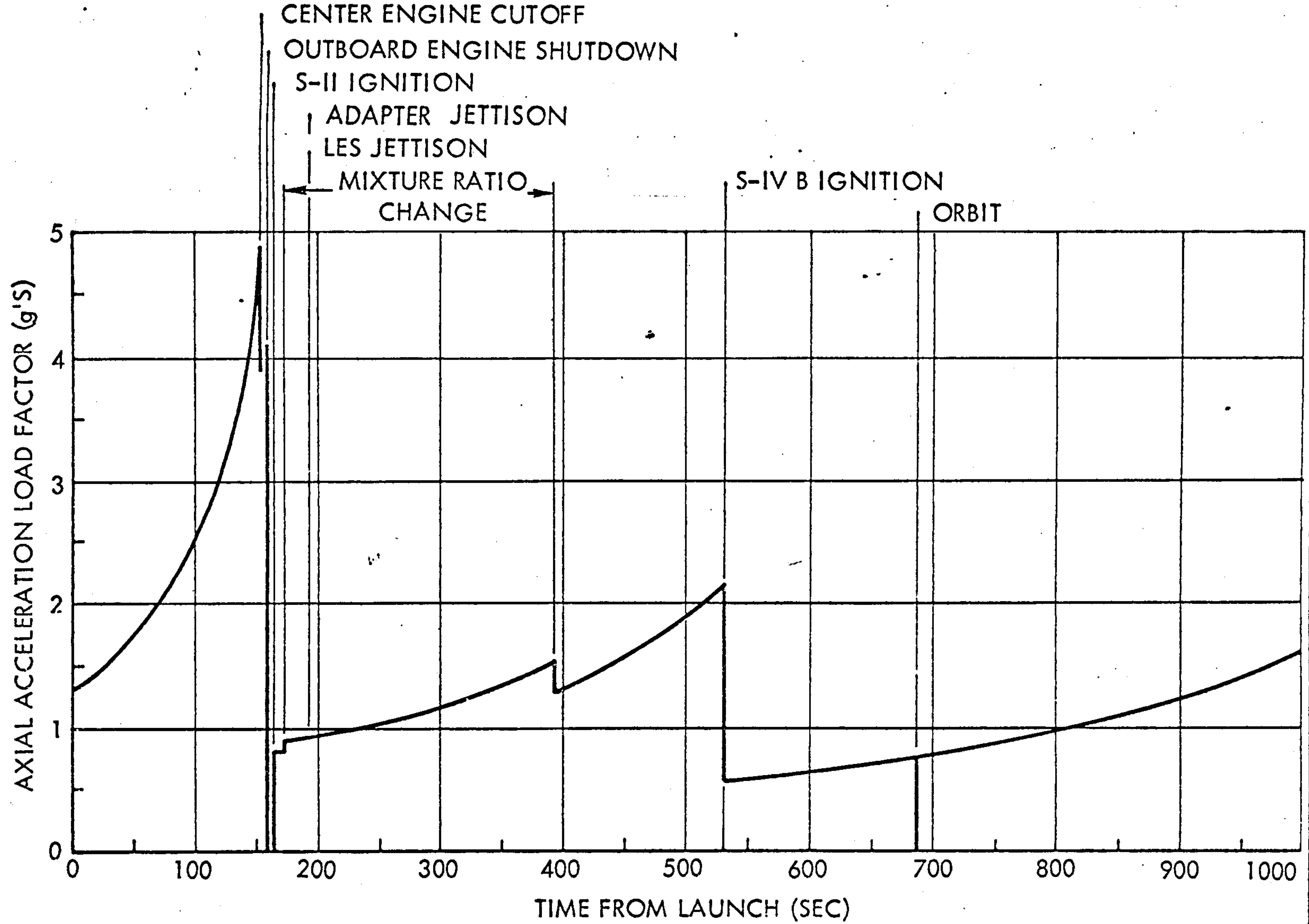


FIGURE 6-1 AXIAL ACCELERATION - NOMINAL SATURN V BOOST (BLOCK II)

6.4.2.4 Vibration Test

Vibration testing will be required for each of the three assemblies of the Qualification Unit in each of three mutually perpendicular axes. The test specimens will not be in an operating mode during vibration testing, however, a complete functional test, in accordance with the NASA approved test procedure, will be performed subsequent to the vibration test. Successful completion of the functional test will verify that the observation and power supply units meet the vibration requirements shown in Figure 6-2 and that the Radiator Experiment Unit meets the vibration requirements shown in Figure 6-3.

6.4.2.5 Shock Test

Shock testing will be required for phase change samples stowed within the Command Module and recovered after the mission. The samples, in the stowed condition, will be subjected to a terminal peak saw-tooth pulse of 78 g (peak amplitude) with total duration 10 to 15 milliseconds, including decay time no greater than 10 percent of the total duration. After the shock test, samples will be optically examined for damage.

6.4.2.6 Humidity Test

A humidity test will be required for each of the three assemblies of the qualification unit which complies with the requirements shown graphically in Figure 6-4. After completion of the humidity test, excessive moisture will be removed from the specimens by turning upside down and wiping external surfaces before the functional test is performed.

6.4.2.7 Electromagnetic Compatibility Tests

An electromagnetic compatibility test will be required to demonstrate that the electrical test specimens operate compatibly under the various conditions of operation of the AAP Mission flying the Phase Change Thermal

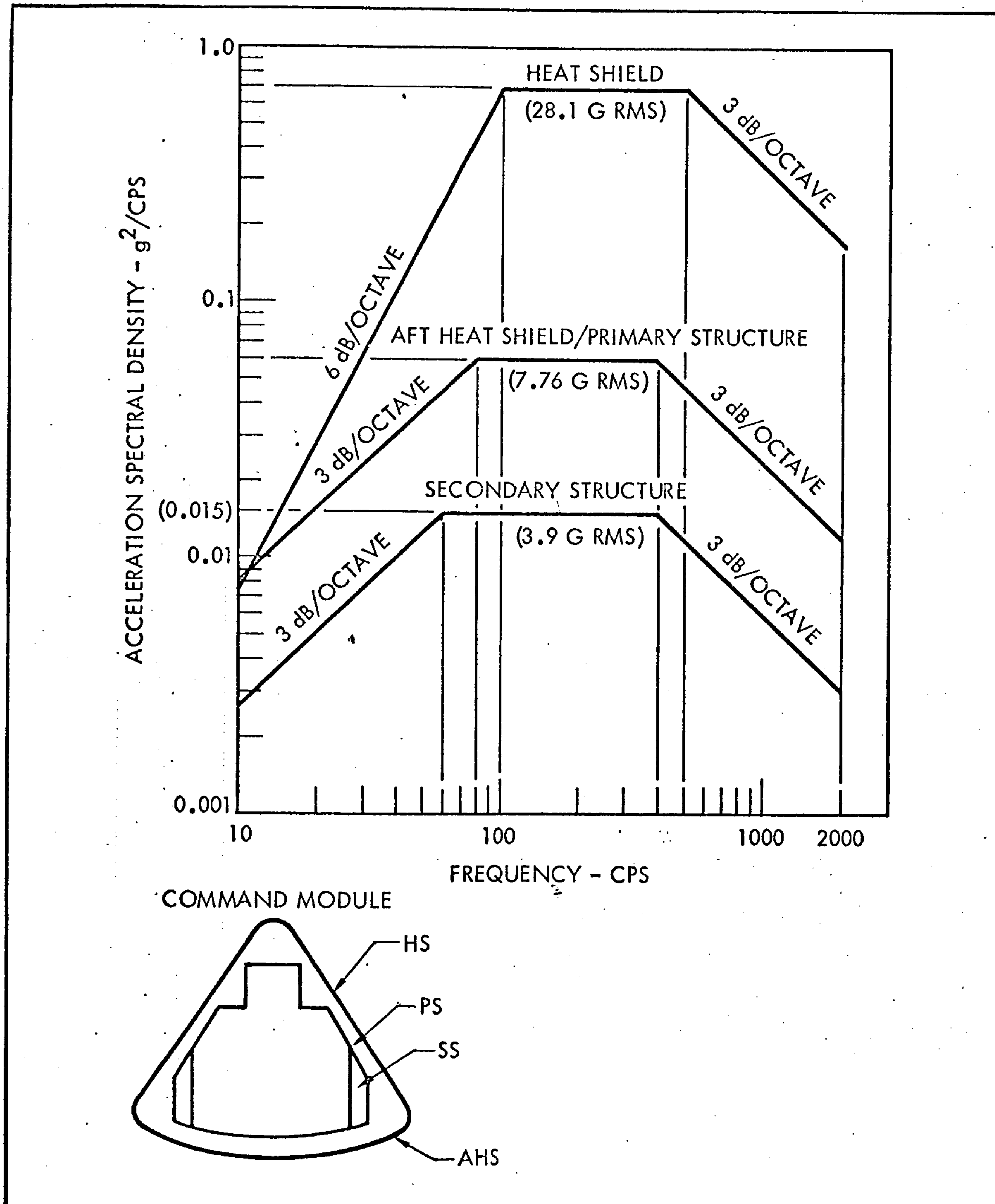


FIGURE 6-2 VIBRATION CM - ATMOSPHERIC FLIGHT (ASCENT)

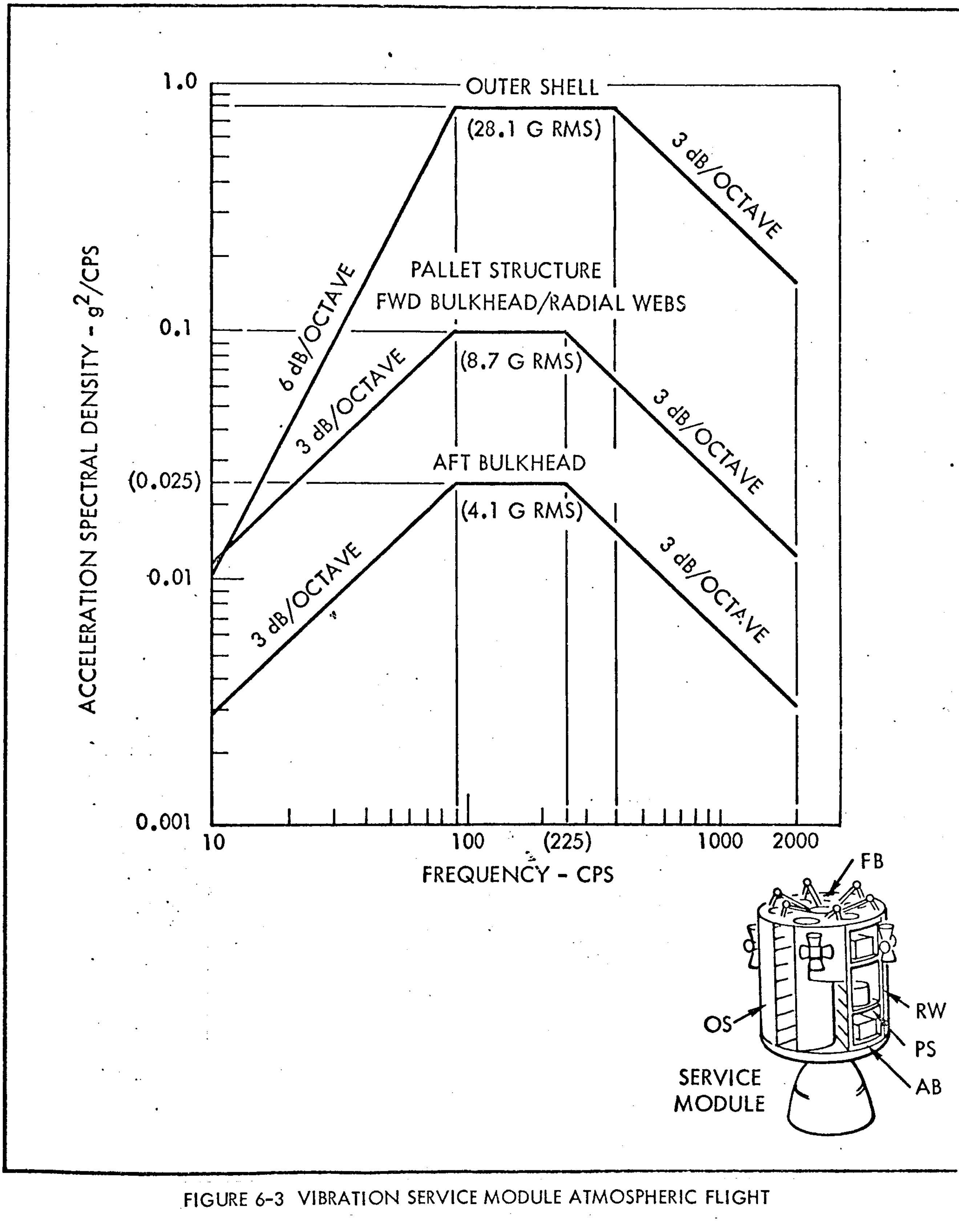
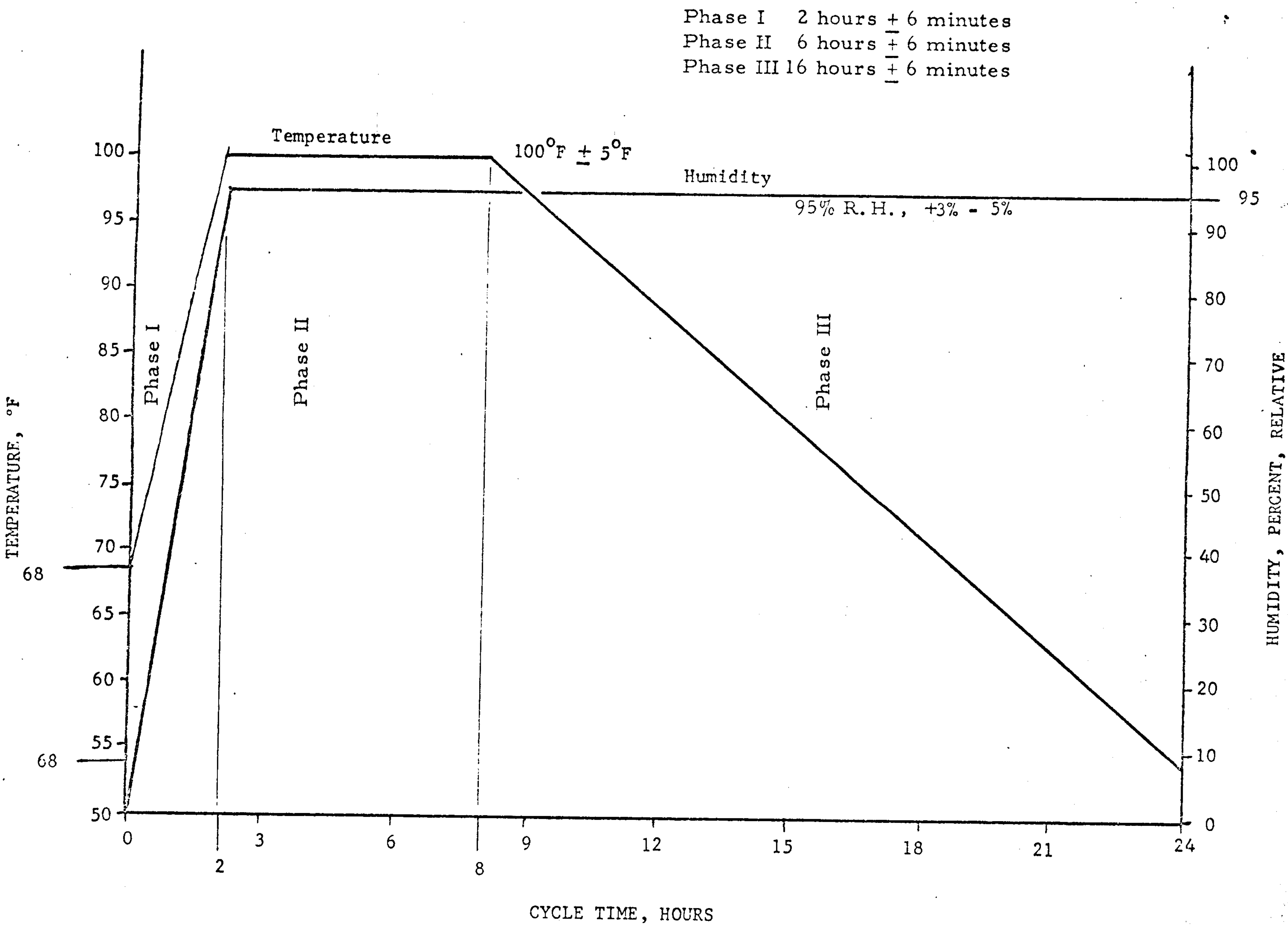


FIGURE 6-3 VIBRATION SERVICE MODULE ATMOSPHERIC FLIGHT



HUMIDITY TEST CONTROL CAM

FIGURE 6-4 HUMIDITY TEST

Radiator Flight Experiment, and to comply with contractual obligations for testing. It is desirable that tests be performed while equipments are operating in all possible modes of operation, with particular attention paid to the modes which are deemed most likely to produce interference and susceptibility.

The general arrangement of the test specimens and their interconnecting cables shall be such as to simulate actual installation insofar as practicable. All power supply voltages to the specimen under test shall be within equipment specification tolerances, and shall be monitored during the course of the tests.

6.4.3 Flight Units

The NASA formal acceptance will be conducted on each Flight Unit after final integration of the subsystems and components have been satisfactorily accomplished. The objective of the acceptance will be to prove that each Flight Unit is built to and will perform within its design specification. The acceptance will culminate in the issuance of a DD-250 Form and will occur at the factory.

After acceptance, the Phase Change Thermal Radiator Flight Experiment will be packed, packaged, and marked in accordance with the requirement of MIL-P-7936A and shipped to the AAP Experiment Integration Center.

At the Experiment Integration Center, a sequence of test operations will validate the Phase Change Thermal Radiator Flight Experiment for installation in and integration with the CSM. The experiment subsystem and interface operations will include:

a) Cabling and Interconnect Equipment - to determine continuity and validate Phase Change Thermal Radiator Flight Experiment, service module radiator protective cover and wiring, and Command Module interface and interconnections.

b) Power Subsystem - To determine that the battery pack output is within tolerance, and that the Observation Unit mechanisms are operating.

c) Data Subsystem - To determine that all planned sensored data is being acquired; that events and experiments data links are functioning; and that data output is within tolerances as to frequency, power, rate, and data format.

6.5 TEST SCHEDULE

The Test Schedule, Figure 6-5, depicts the 30 working day qualification test program for the Phase Change Thermal Radiator Flight Experiment.

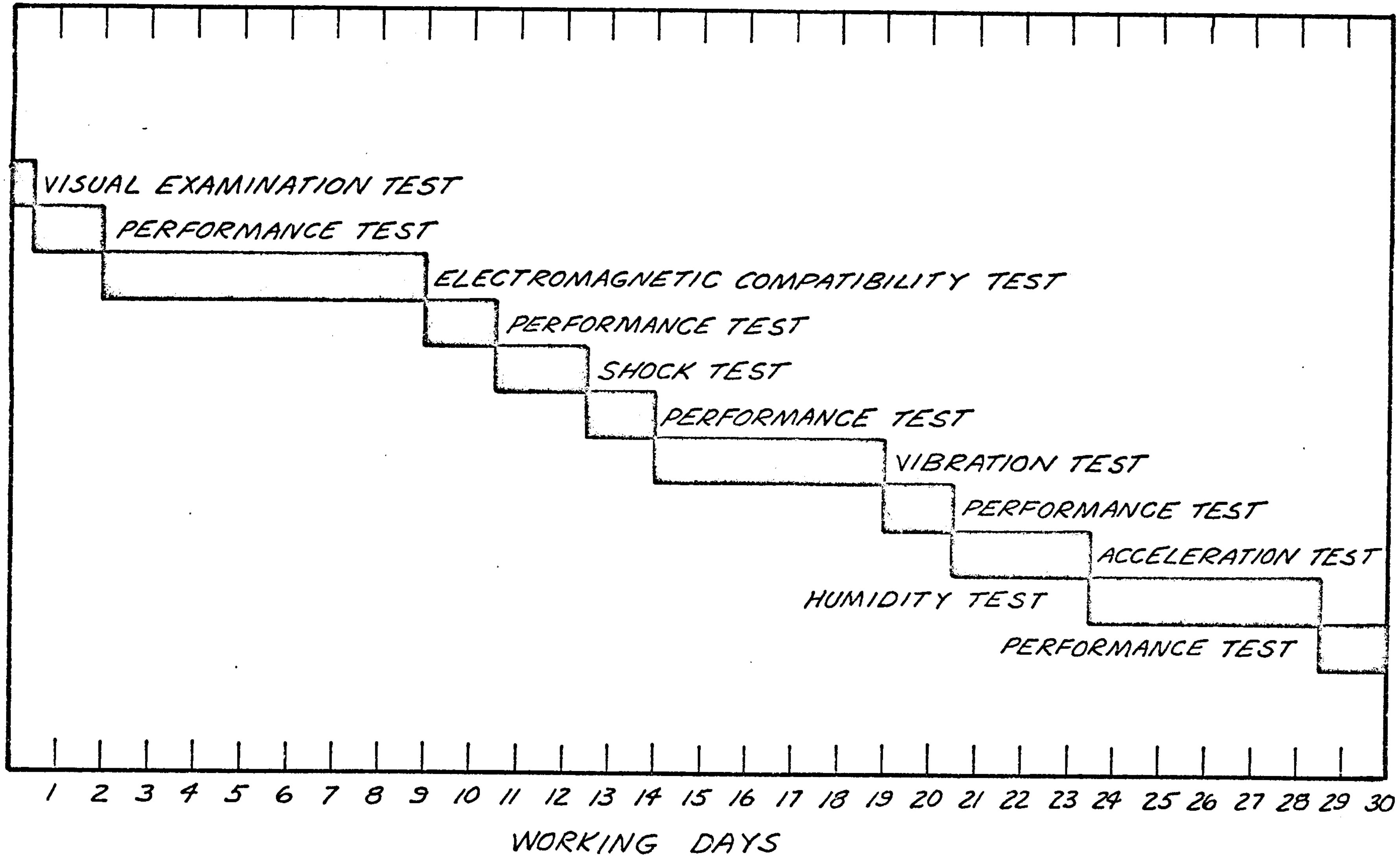


FIGURE 6-5 TEST SCHEDULE

NSL 67-207

FACILITIES PLAN

SECTION 7

CONTENTS

ILLUSTRATIONS

7.0 FACILITIES PLAN

7.1 INTRODUCTION

The major portion of the PCTR Phase D manufacturing effort will be conducted in the Northrop Systems Laboratories facility which is centrally located within the Northrop Hawthorne Complex. Supporting fabrication and test facilities are located adjacent to this facility. All of the facilities and equipment required to support the planned manufacturing effort on the Phase D PCTR Program are immediately available within the Hawthorne Complex and no new buildings or machinery are required to support the program.

7.2 AREA CHARTS

The Northrop Systems Laboratories, its location within the Northrop Hawthorne Complex, and the physical relationship of the Northrop Systems Laboratories Facility to the PCTR Program support areas is shown as Figure 7-1 and 7-2.

A detail layout of the Northrop Materiel Facility is shown as Figure 7-3.

The Northrop Tooling Building Facility, where the PCTR fabrication and assembly tools will be built is shown as Figure 7-4.

A layout of the adhesive bonding facility, used to fabricate the radiator panels is shown as Figure 7-5.

The Machine Shop section of the Northrop Advance Production Shop which will be used to perform some of the machining operations on the subsystem details is shown as Figure 7-6.

The PCTR Manufacturing Facility which is used for most of the fabrication effort, and all of the assembly tasks to be conducted by the manufacturing organization on the PCTR Phase D Program is shown as Figure 7-7.

7.3 DESCRIPTION OF NORTHROP FACILITIES APPLICABLE TO THE PCTR PROGRAM

Northrop Systems Laboratories Building

This 240,000 square foot building houses complete Research and Development Laboratories equipped to support systems engineering and instrument fabrication programs. Modern manufacturing areas are equipped for experimental and prototype fabrication as well as quantity production. The building has a five-story wing containing 136,000 square feet of office and laboratory space and 20,400 square feet of high bay area. Of the total square footage, Northrop has available sufficient space for the efficient accomplishment of the PCTR program as required. This allocated area is immediately available for occupancy.

Electronics Development Laboratory

This laboratory uses the latest techniques and equipment for the development and test of electronic circuitry and equipment. The laboratory equipment includes high speed pulse analyzing equipment in addition to all of the equipment normally used in such diverse fields as digital techniques, transistor circuit development and vacuum tube circuit development. Specialized electronic microminiaturization welding equipment, together with vacuum facilities and environmental simulation equipment also located in the laboratory, supply key electronic hardware capability. Some typical facilities are shown in Figures 7-8 and 7-9.

The laboratory is centrally located within the NSL building, thereby providing ready access to other nearby environmental and test laboratory facilities, which have complete extensive equipment for materials testing, vibration, space vacuum, humidity, and virtually all other environmental test capabilities.

Electrical and Electronic Engineering Support Laboratory

Fabrication of the equipment required on this program will be performed in the Electrical and Electronic Engineering Support Laboratory. This laboratory is equipped for experimental and production fabrication of all types of electronic components, subsystems and systems. Some of the available equipment is shown in Figures 7-10 and 7-11.

This laboratory includes 5,600 square feet of air conditioned area on the first floor of the Northrop Systems Laboratories Building. It is equipped with all required utilities including 110 volt, 60 cycle, single phase; 110 volt, 400 cycle, single and three phase; and 220/440 volt, three phase 60 cycle power. Plant vacuum lines, air lines, gas, and cooling water lines are also available. Lqiuid nitrogen is available from a large LN_2 storage tank just outside the South High Bay. This laboratory is completely equipped with the latest electrical and electronic instrumentation and equipment to support the fabrication effort of the PCTR program.

Receiving Inspection and Process Control Facilities

These facilities are equipped to perform any acceptance test required for material or equipment used in all NSL contracts on missile and spacecraft hardware built to NASA requirements. Present facilities include an automatic semiconductor test unit capable of testing sixteen semiconductor parameters at the rate of 250 semiconductor units per hour, with all data recorded on IBM cards. Additional capabilities include environmental facilities for acceptance testing of functional parts and components under simulated environmental conditions; ultrasonic inspection equipment; a direct reading spectrometer for rapid quantitative chemical analysis of metallic raw stock; and a multienvironmental fluoroscopic test facility permitting both fluoroscopic observation and recording of component internal functioning under combined vibration, pressure, and temperature environments. Some typical examples of receiving inspection equipment are shown in Figures 7-12 and 7-13.

Space Environment Laboratory

Space testing of the PCTR system may be accomplished in the Space Simulation Laboratory located in Northrop Systems Laboratories high bay area.

This laboratory includes three space simulation vacuum chambers The principal chamber consists of a main tank 12-feet in diameter by 15 feet long with an 8-foot diameter by 10-foot long personnel entry lock, and a 3-foot diameter by 8-foot long decompression tank. The main chamber is fitted with a full-diameter rollback door which has provisions for mounting specimens weighing up to 10,000 pounds. The total pumping system incorporates mechanic diffusion and cryopumping components to provide normal operation in the pressure range of 10^{-7} Torr with test specimens installed. Ultimate minimum pressure capability is in the 10^{-9} Torr range, and maximum pumping speed exceeds 300,000 liters/sec. This chamber system includes a cold-wall installation capable of maintaining 100K with a total contained heat load of 20,000 watts, and with localized loads of 150 watts/ square foot.

The second chamber consists of a shell five feet in diameter by seven feet long. Complete cold walls and pump baffles have been installed, and other associated equipment includes spectrally compliant solar simulation. The vacuum pumping system consists of a 32-inch oil diffusion pump and a mechanical roughing pump providing the ability to operate in the 10^{-7} Torr pressure range.

The third chamber is a mild steel shell 30 inches in diameter by 6 feet high with a vacuum tight, stainless steel inner shell. The space between the two shells is evacuated and utilized as a guard vacuum. Liquid nitrogen is used to cool the inner shell to temperatures below 100 K for simulating the heat sink of space. The pumping system consists of two oil diffusion pumps in tandem and a mechanical roughing pump. The operating pressures of the chamber is in the 10^{-7} Torr range. These NSL Space Simulation vacuum chambers are shown in Figure 7-14.

Horizontal vibration tests are conducted on oil slip tables or on a precision hydraulic horizontal table. The largest electrohydraulic shaker has a force rating of 96,000 pounds, a maximum stroke of seven inches, and a frequency range of 2 to 200 cps.

A variety of impact shock machines are located within the laboratory and are available for use on this program.

A 10-foot diameter centrifuge and a 2-foot diameter centrifuge are available for use. The larger centrifuge can generate 133 g on a 70 pound specimen or 1 g on a 2669-pound specimen.

Testing can be accomplished in the areas of atmosphere exit and re-entry heating simulation. Ten separate programmed channels are available, nine for radiant or resistive heating and one for induction heating. Power available for the nine channels is 1500 kv; 100 kv is the output of the induction heater.

Altitude testing is accomplished in facilities ranging in size from a portable 3 by 3-foot chamber to an 11 by 20-foot chamber, in which altitudes to 120,000 feet are attainable. Controlled temperatures from -90 F to +200 F are attainable in these chambers.

Chambers for extreme temperature testing are available in sizes ranging from a cube 5 feet on a side to 15 by 50 by 9 feet. These chambers attain temperatures ranging from -100 F to +300 F. Liquid nitrogen injection is employed for rapid decreases in temperature to produce temperature shock. These chambers are also explosion proof.

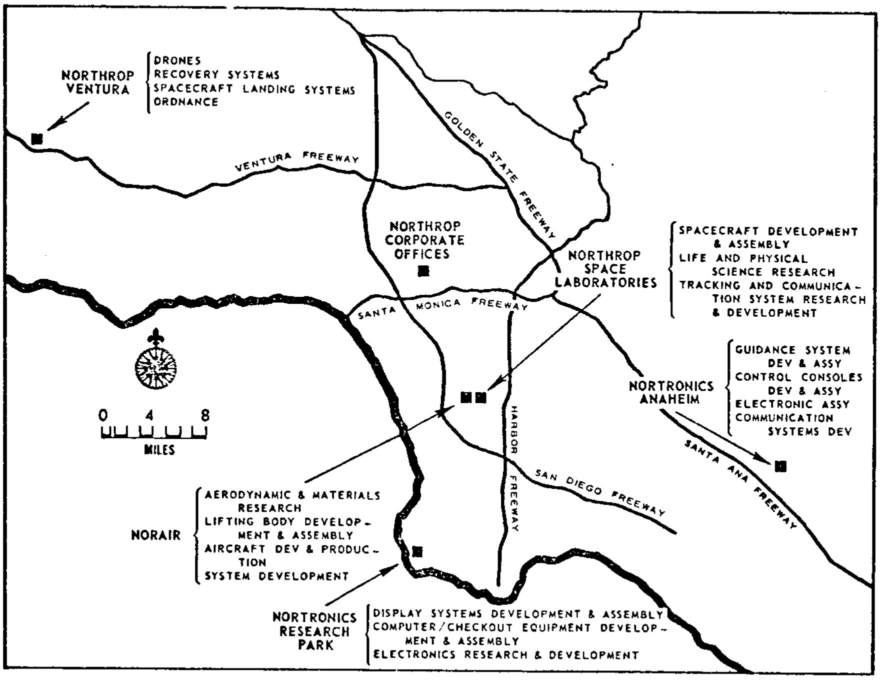
Humidity chambers are available in which noncondensing humidities as low as 50 percent and relative humidities of 100 percent can be developed. Temperature ranges up to 160 F may be attained.

Sand and dust chambers are available that will provide particle velocities up to 2300 ft/min at temperatures as high as 160 F.

Extensive facilities are available, if required, for conducting structural tests on aerospace components. A variety of repeat load and fatigue test machines are capable of creating a maximum static force of 500, 000 pounds and a maximum alternating force of $\pm$ 250, 000 pounds in a frequency range of 30 cpm to 1600 cpm. Space craft mounting frameworks are available for structural static testing. These frameworks can be assembled into structures capable of reacting to concentrated loads. Automatic data recording equipment is used to record force (strain gage outputs) as well as structural deflectors.

Painting Facility

This facility (Figure 7-9) located in the Southeast corner of NSL's high-bay area, consists of a 240-square-foot clean room type paint spray booth with 7, 000 cfm laminar flow incoming air filtered through Class AEPA filters. The entire facility conforms to Class 100, 000, Federal Standard 209 and is equipped with drying racks and film thickness measuring instruments in addition to explosion proof lights and electrical outlets. The room is maintained under slight positive pressure to preclude contamination.



NORTHROP HAWTHORNE COMPLEX

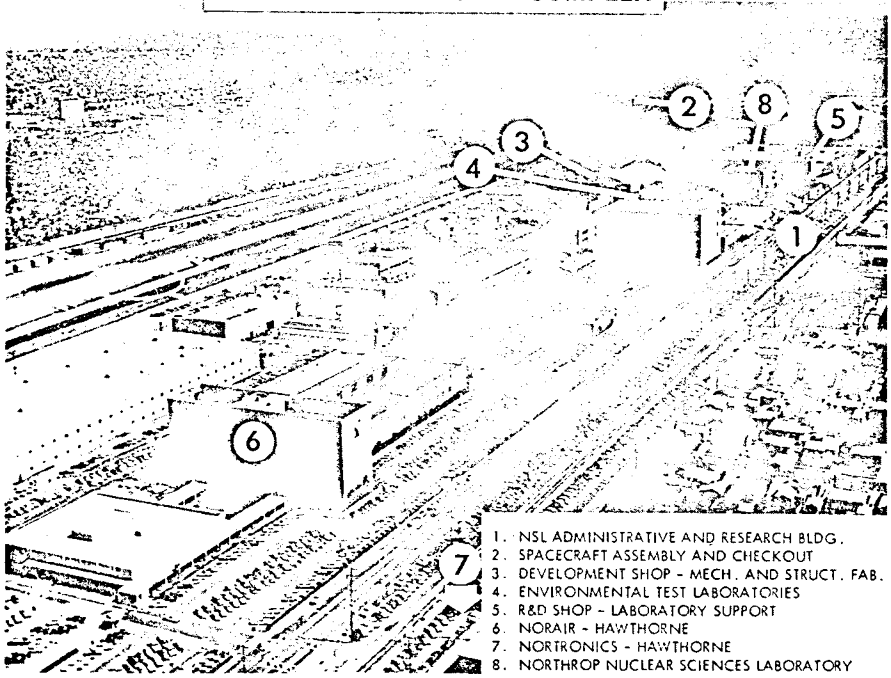


FIGURE 7-1 NORTHROP CAPABILITIES IN LOS ANGELES AREA

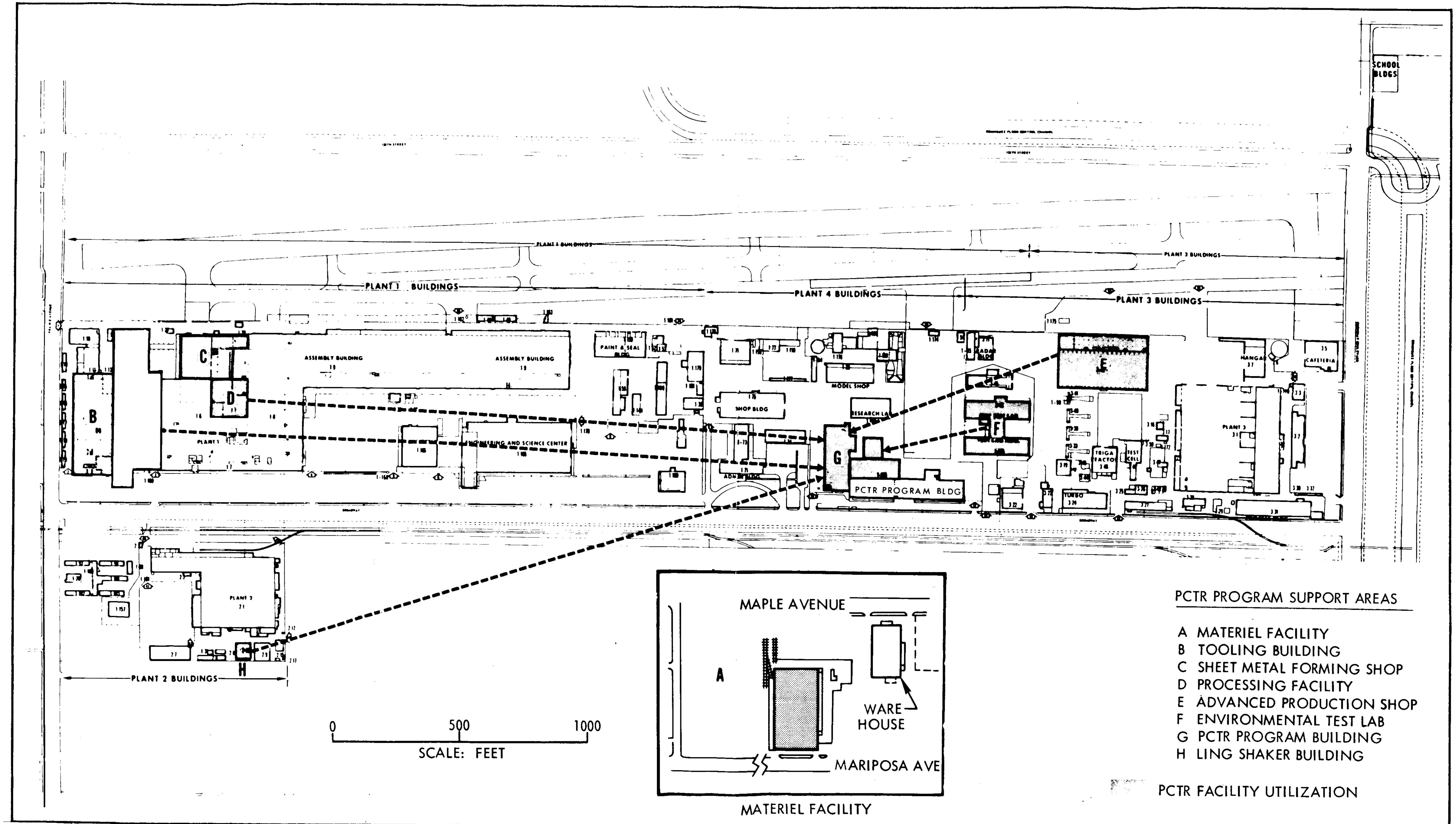


FIGURE 7-2 NORTHROP HAWTHORNE COMPLEX - PCTR FACILITIES UTILIZATION AREA

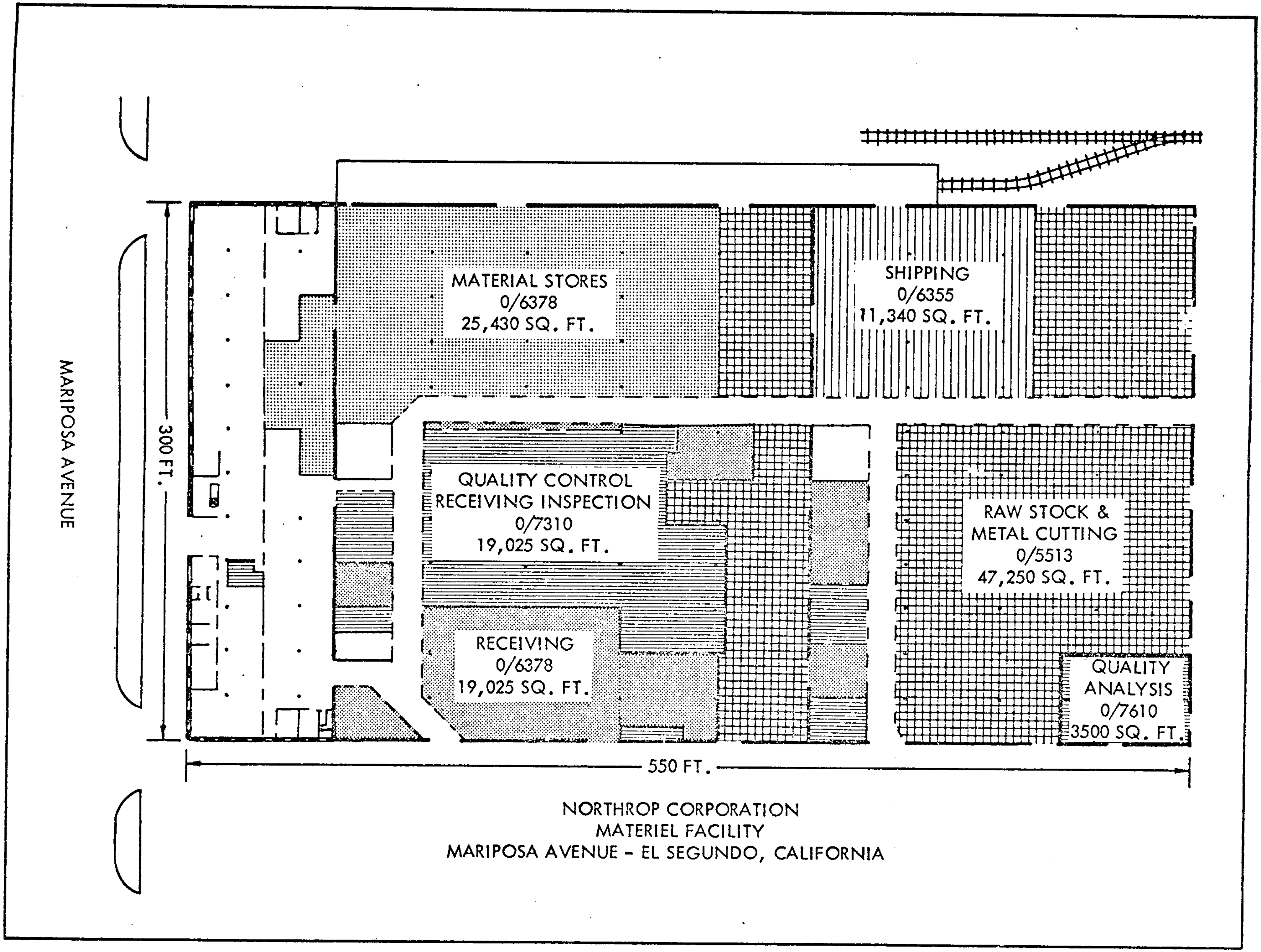


FIGURE 7-3 MATERIEL FACILITY

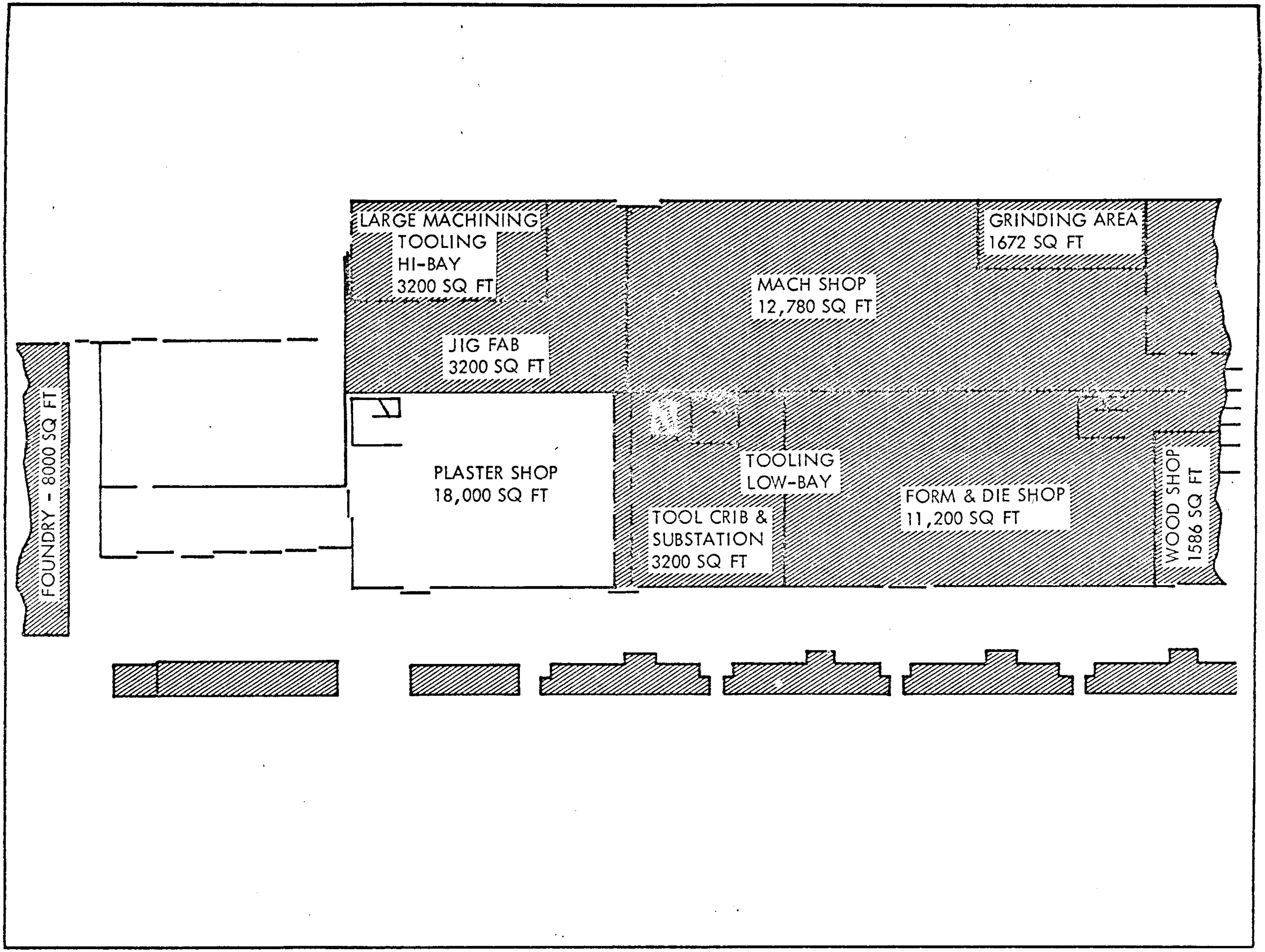


FIGURE 7-4 TOOLING BUILDING FACILITY

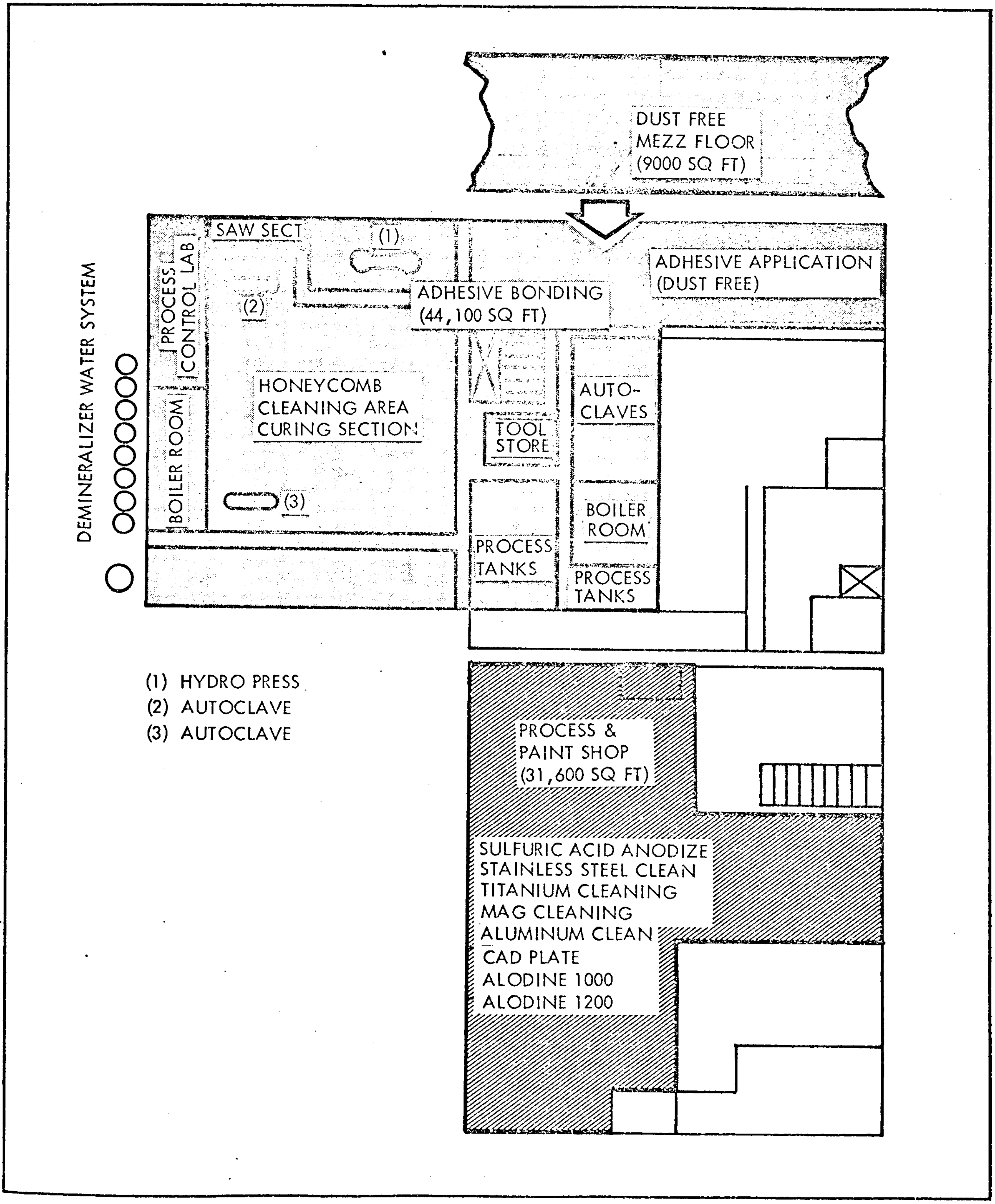


FIGURE 7-5 ADHESIVE BOND SHOP FACILITY

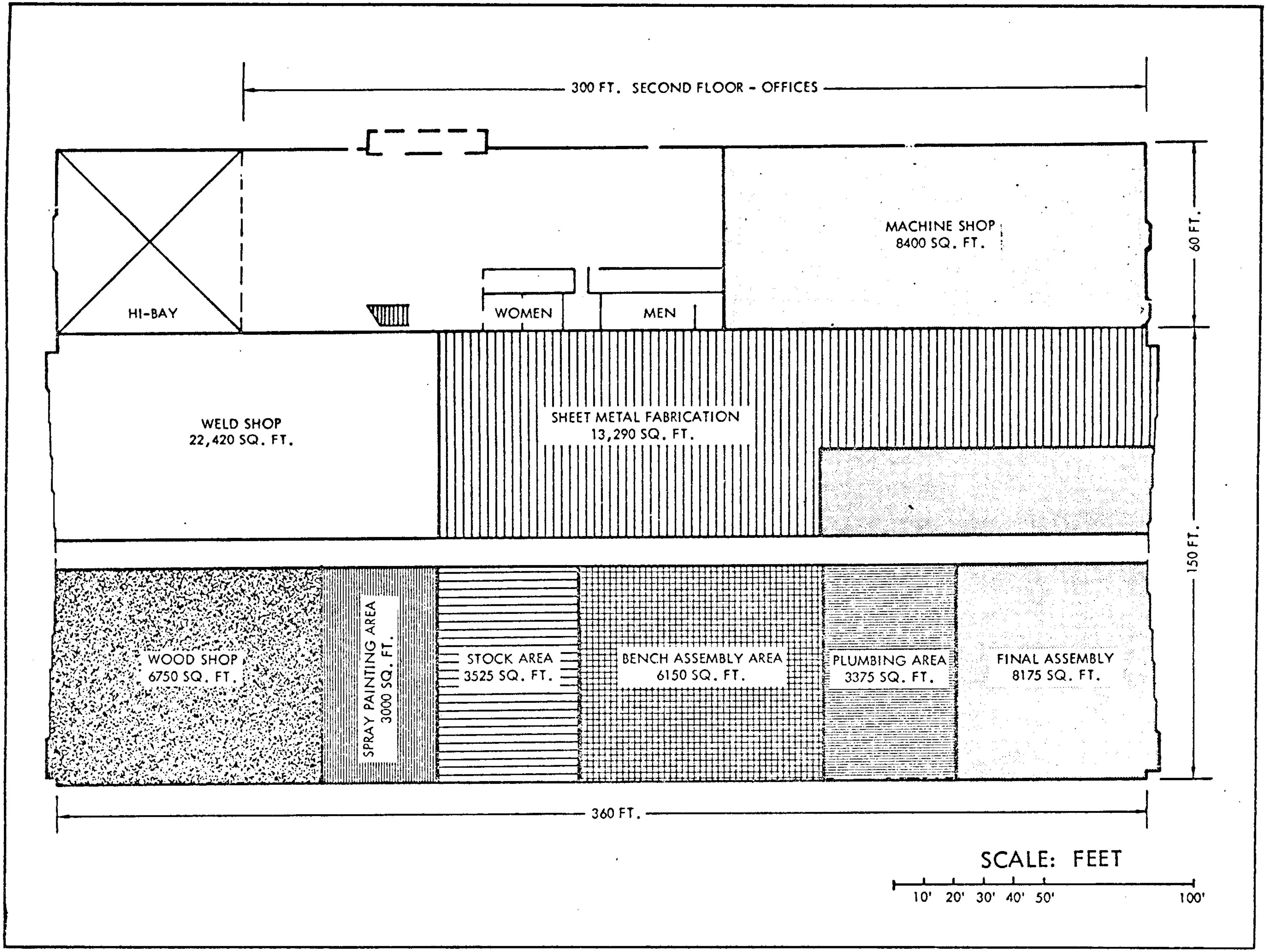


FIGURE 7-6 ADVANCED PRODUCTION SHOP FACILITY

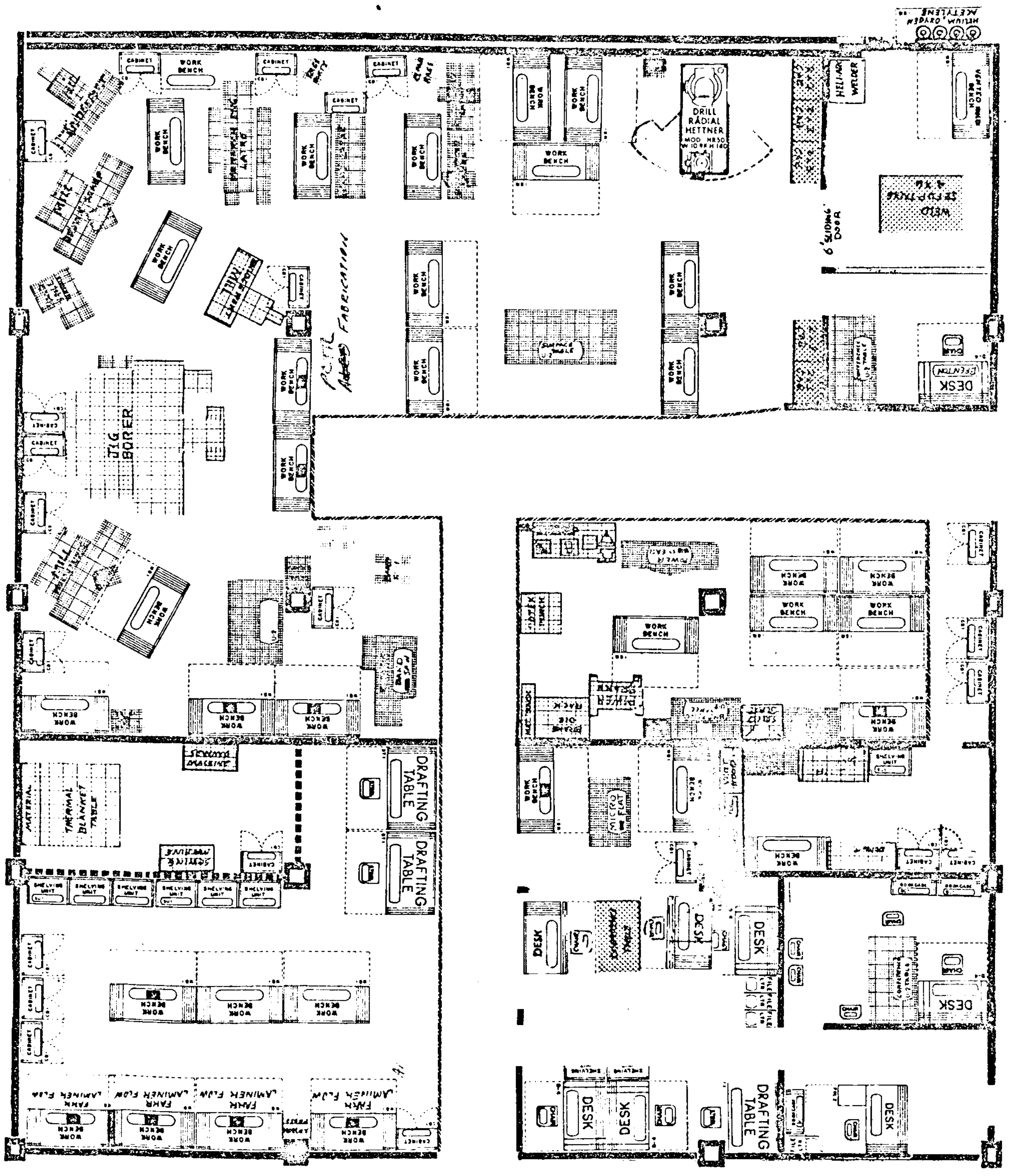


FIGURE 7-7 PCTR MANUFACTURING FACILITY

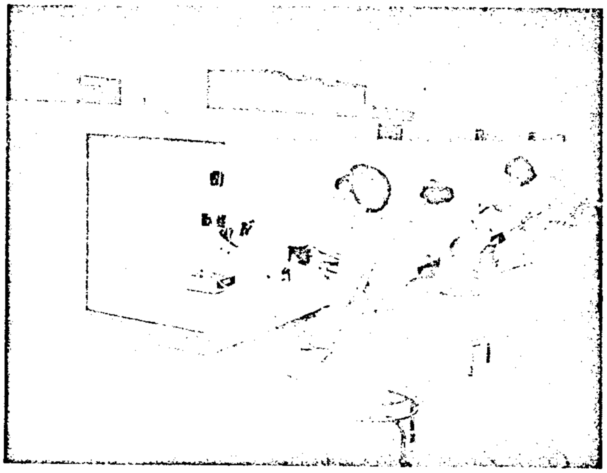


FIGURE 7-8 CLEAN BENCH SUB-ASSEMBLY AREA

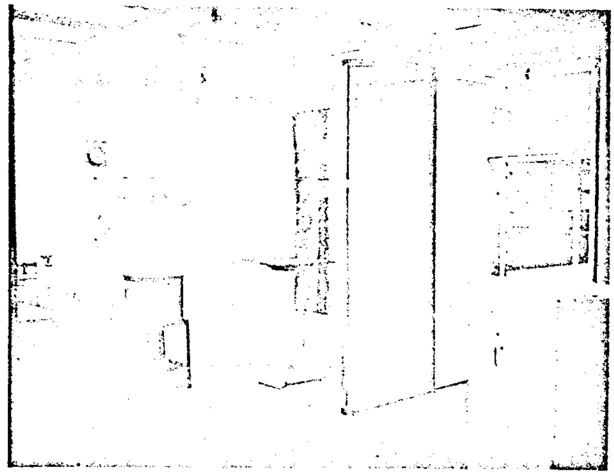
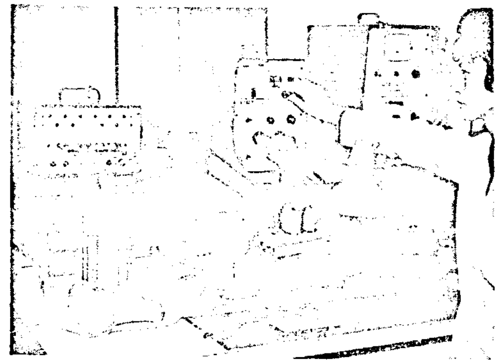


FIGURE 7-9 PORTION OF CLEAN ROOM THERMAL COATING SPRAY BOOTH

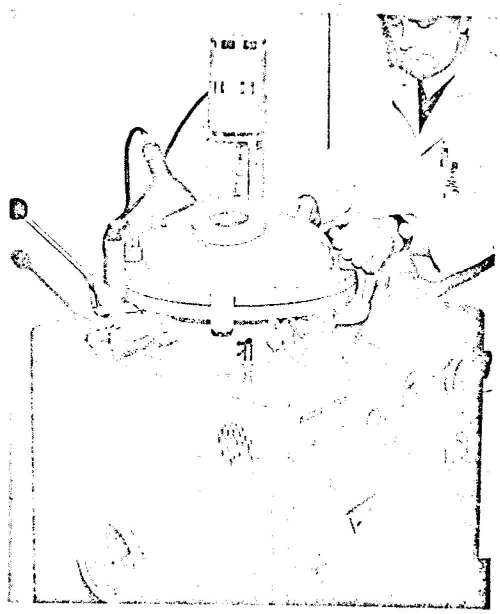
ELECTRONIC MODULE WELDING EQUIPMENT

This is a typical module welding station located in the Electronics Lab



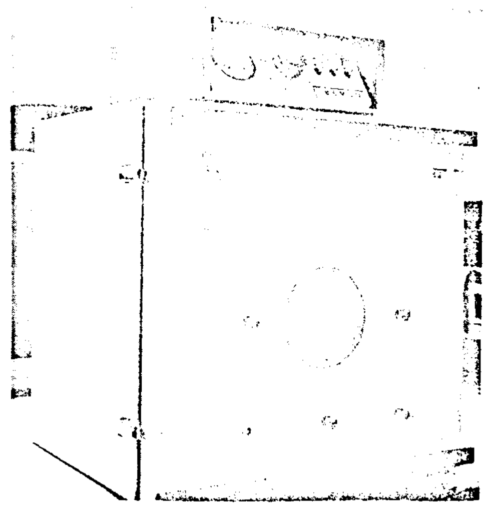
VACUUM ENCAPSULATOR

This equipment is used for potting various types of welded electron modules



TEST CHAMBER

This chamber is used for high and low temperature environment evaluation



PULL TESTER

This device is used to check the breakpoint of weld samples used in electronic modules

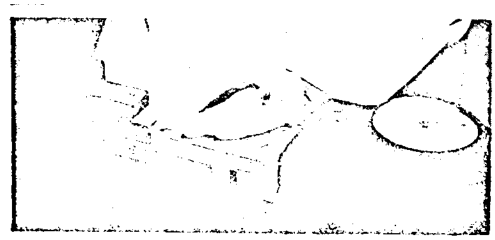
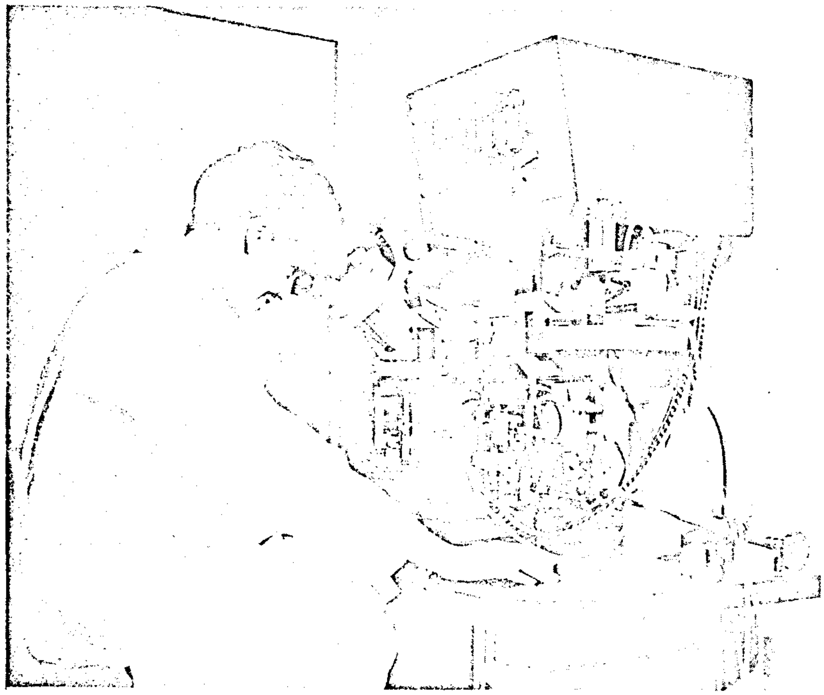


FIGURE 7-10 ELECTRICAL ENGINEERING SUPPORT LABORATORY

MICROMANIPULATOR

This high-precision device is used to position sub-miniature elements for assembling into various components



VACUUM CHAMBER

This chamber is used for deposition plating work

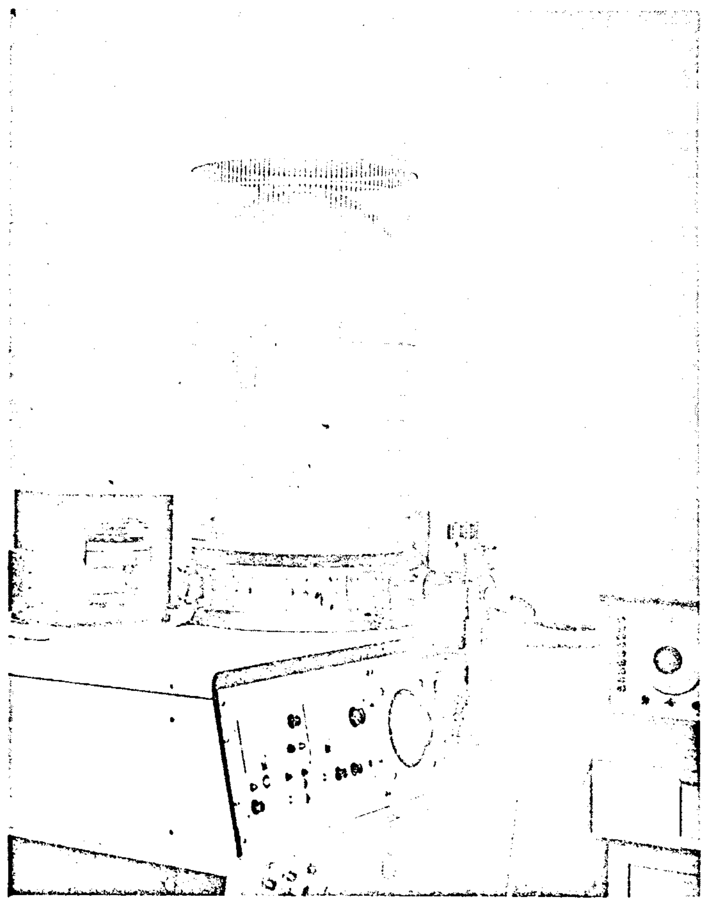
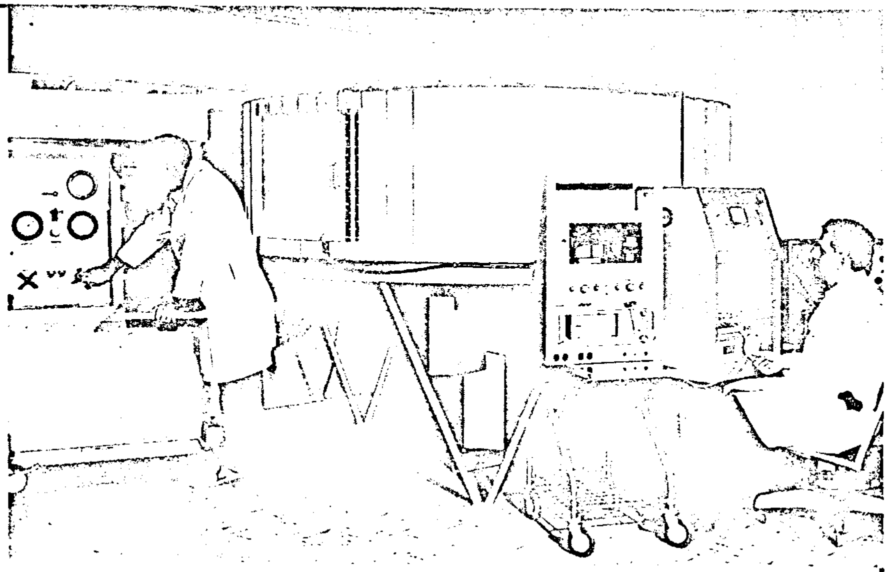


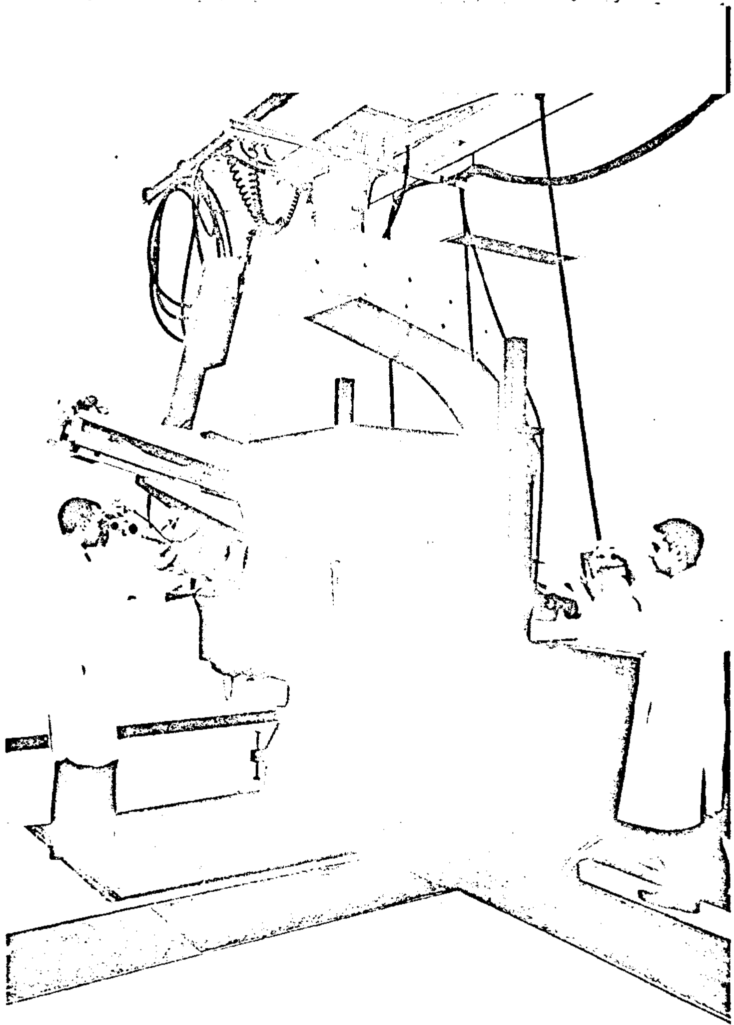
FIGURE 7-11 ELECTRONIC ENGINEERING SUPPORT LABORATORY

FIGURE 7-12



"G" ACCELERATOR.
Electronic assemblies are subjective to high acceleration during verification of qualification tests.

FIGURE 7-13



FLUOROSCOPIC TEST SYSTEM.
This equipment provides the capability to x-ray a test article under a multi-environment - Vibration, Temperature and Altitude.

TYPICAL RECEIVING INSPECTION EQUIPMENT

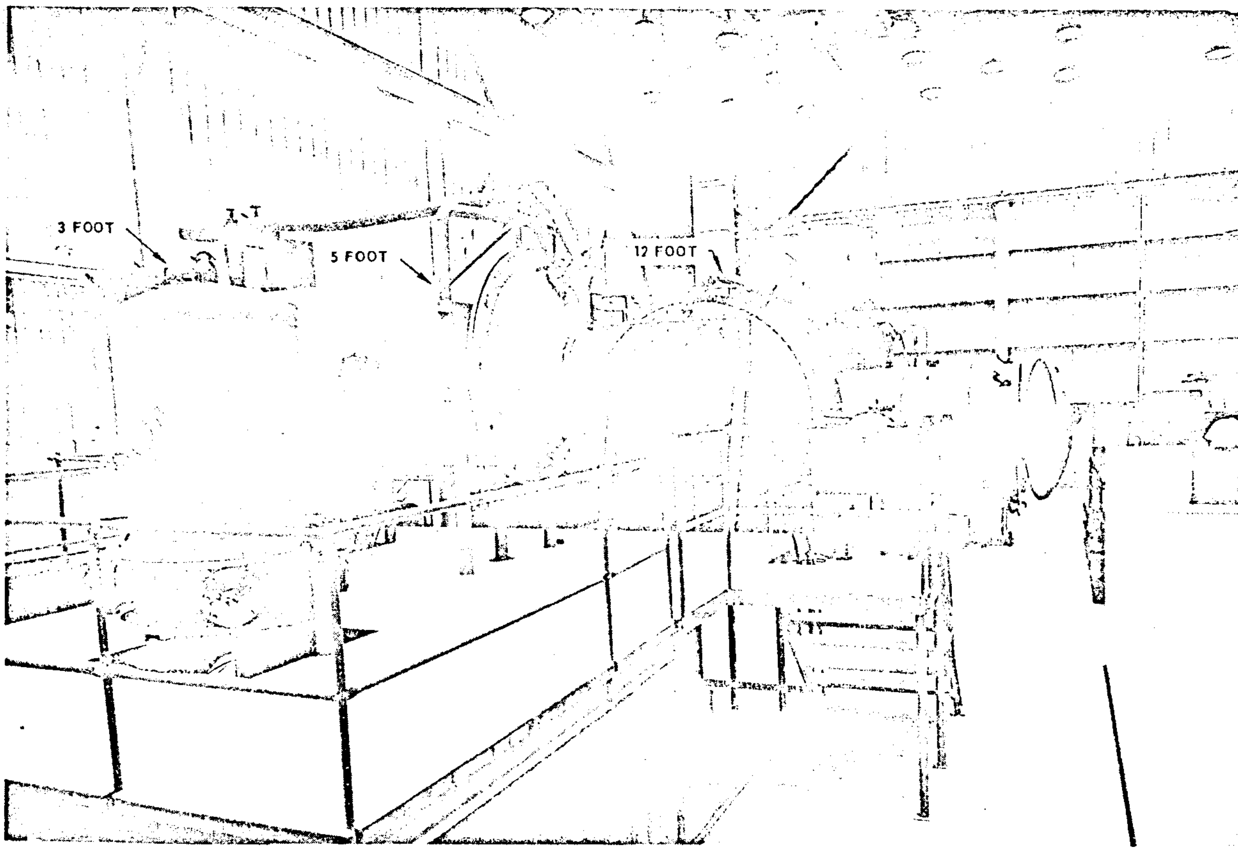


FIGURE 7-14 VACUUM SPACE CHAMBERS

NSL 67-208

LOGISTICS PLAN

Section 8

CONTENTS

8.0 LOGISTICS PLAN

8.1 Introduction

8.1.1 SUPPORT REQUIREMENTS

The Logistics Plan is prepared in response to the Statement of Work (SOW), Article 1, paragraph 8, under NASA Contract NAS 8-20670. The plan covers the support requirements for the Phase Change Thermal Radiator Program in the areas of logistics, maintenance, packaging, storage, handling, and transport of models, flight articles, spares, and GSE; and delineates the procedural means, or procedures, for satisfactory accomplishment of these activities. The Northrop point of contact for the support activities covered herein lies in the Operations Group of the PCTR Program Organization (see Figure of the Management Plan, NSL 67-201). The Operations Group is responsible for providing the documentation (plans, procedures and/or manuals) and implementing the activities covered by this plan. This plan will be updated as required. Such revisions will be accomplished by furnishing revised, amended, or additional pages as appropriate.

8.1.2 SUPPORT OPERATIONS

Northrop will provide support as follows:

a. Apollo Contractor Support

b. CM Contractor Support

c. NASA PCTR Evaluation and Training

d. NASA/KSC Prelaunch Operations

e. Northrop Factory Support Operations

8.1.2.1 Apollo Contractor Support

Northrop will provide the orientation and support required to integrate the PCTR prototype into the CM at the Apollo contractor's facility. This support will include Northrop and Apollo contractor interface meetings to establish the detailed Northrop support requirements, the preparation of a detailed PCTR Logistics Plan for NASA approval, and the implementation of the Logistics Plan.

8.1.2.2 CM Contractor Support

Northrop will provide orientation and support required to support the PCTR requirements for the CM thermal/vacuum tests and the CM flight tests. This support will include Northrop and CM contractor interface meetings to establish the detailed Northrop support requirements, the preparation of a detailed PCTR Logistics Plan for NASA approval, and the implementation of the Logistics Plan.

8.1.2.3 NASA PCTR Evaluation and Training

Northrop will provide support at NASA/MSFC and/or other NASA designated locations in support of PCTR orientation, familiarization, and preliminary support planning operations. The preliminary support planning operations will serve to establish detailed Northrop support requirements to aid NASA in the accomplishment of PCTR evaluation and training requirements. The NASA activities considered in this support will include evaluation and training.

8.1.2.4 NASA/KSC Prelaunch Operations

Northrop will assist the CM contractor at NASA/KSC in support of the PCTR checkout installation, installation into CM. This support activity will take place primarily in the Mission Support Operations Building, MSOB, and will consist of a detailed visual examination of the PCTR System for physical damage and gross go-no-go checkout of the system.

Any malfunction of the PCTR will require the use of the backup flight unit.

No repairs or overhaul maintenance activities will be performed on the PCTR at NASA/KSC, except GSE.

8.1.2.5 Northrop Factory Support Operations

PCTR repairs and/or overhaul maintenance operations will be performed at the Northrop Hawthorne Factory. All such repair and/or overhaul operations will require the conduct of acceptance tests prior to return of the PCTR to NASA. Factory spares will be utilized in support of the factory repair and/or overhaul maintenance operations. Refurbishment of salvable parts will be accomplished by Northrop or the original part supplier. Parts damaged or worn beyond repair will be disposed of only upon NASA approval.

8.2 Support Criteria

The following subparagraphs describe the criteria employed in maintenance and overhaul activities for the PCTR and ancillary equipment, and the definition of terminology applied thereto.

8.2.1 EQUIPMENT MAINTANANCE AND OVERHAUL

Maintenance and overhaul will be performed to the following criteria.

a. Electrical/Electronic Equipment (either installed or on the bench) - Checkout and replacement will be at the component (black box) level. A black box is defined as a combination of factory replacement units which are contained within a physical package as an integral unit.

b. Non-electrical/Electronic Equipment (either installed or on the bench) - Checkout and replacement will be at the lowest replaceable serialized component level which includes only those components removable as integral units from the PCTR system. Bench test equipment will be used for malfunction verification of components removed from the PCTR because of suspected failure. Bench test equipment will be used for spares verification prior to installation.

c. Shelf Life - The PCTR will be capable of fulfilling its mission after being stored for two years with minimum refurbishment film and batteries. After any storage, the PCTR will be operationally checked to determine its operability level. Any malfunction, or degradation of operations noted in comparing against previous test data, will result in component replacement and/or overhaul.

d. Failure Reports - A failure report will be prepared on all failures occurring on PCTR hardware. Any failure will be reported to NASA by TWX within 24 hours after failure occurs. The report will contain a description and analysis of the failure, and corrective action taken and/or proposed.

e. On-Site Accessibility (KSC) - There will be access to the PCTR storage compartment at about five (5) days before launch for installation of the battery and liquid LN_2. All other checkout and maintenance on the PCTR will be accomplished prior to T minus forty (40) days.

f. On-Site Maintenance (KSC) - Scheduled and unscheduled maintenance on site will not be required as checkout activities on-site consist only of visual inspection and go/no-go operating checks to determine if the equipment has been damaged in transit. If damage has occurred, the item so damaged will be returned to Northrop/Hawthorne for rework, tested and reshipped, or replaced from spares on site, or from backup units. Batteries will be activated at KSC and checked with a bench test voltmeter for proper voltage level prior to installation in the PCTR.

g. Ground Support Equipment (GSE) - On-site GSE will not be required as only visual inspection and a go/no-go operating check will be performed at KSC. The go/no-go check will be made using a test battery or simulator for power.

8.3 Spares

8.3.1 PCTR SYSTEM (LESS BATTERIES)

Spares provisioning will be specified by NASA in the Statement of Work for Phase IV. The second Flight Unit 1, will provide one complete backup system. Upon delivery at KSC, the systems will be removed from their shipping containers and inspected, including analysis of shipping instrumentation data per Paragraph 8.5.2, for transport or handling damage. Upon satisfactory verification that no damage has occurred to either system, the first flight unit will be installed by the PCTR contractor for launch and the second flight unit either becomes primary equipment for a second launch or becomes a backup unit. In the event a system component is damaged, it will be returned to the factory for rework, test and reshipment to KSC.

8.3.2 BATTERIES

Spares provisioning for the batteries will be similar to that for the rest of the PCTR System. A minimum of three battery sets will be shipped to KSC for the two PCTR Systems delivered. Two spare batteries will be available for the first flight. If the spare for Flight Unit 1 is not used on that flight, it becomes the spare for Flight Unit 2. Disposition of the unused spares will be as directed by NASA.

8.3.3 DOCUMENTATION

The Program Administrator will define, establish, and maintain records for the PCTR Program to assure efficient control of the equipment, flight articles and spares, GSE, and test equipment, and the flow of repairable items between Northrop and NASA sites. These records are used for determining subsequent spares requirements, provisioning and schedules.

8.3.4 DISTRIBUTION AND CONTROL

All equipments and spares delivered to NASA will be through the PCTR Operations Group. This group will maintain records as described in paragraph 8.3.3.

8.3.5 DISPOSITION OF OBSOLETE SPARES

Spares determined to be obsolete for the PCTR Program will be reported to NASA for disposition instructions.

8.4 Transportation

8.4.1 FLIGHT ARTICLES

After being packaged as specified in paragraph 8.5, flight articles will be transported from Northrop/Hawthorne to KSC or MSFC. Shipment will be made by a common carrier, preferably by air freight. However, Government air transport will be utilized as directed by NASA. Routing to KSC for the two modes is as follows:

a. Air Freight - From Northrop/Hawthorne to Los Angeles International Airport by truck, Los Angeles to Chicago by Flying Tiger Airlines, Chicago to Orlando by Air Lift International, Orlando to KSC by truck.

b. Government Air - From Northrop/Hawthorne to Los Angeles International Airport by truck, Los Angeles to Patrick Air Force Base by air, Patrick AFB to KSC by truck.

8.4.2 MODELS AND SIMULATORS

After being packaged as specified in paragraph 8.5, models and simulators will be transported from Northrop/Hawthorne to the destinations, as specified by NASA, by common carrier.

8.4.3 SHIPMENT SEQUENCE (FLIGHT ARTICLES)

To provide the greatest assurance of operable, undamaged, equipment delivery, the shipment of Flight Unit 1 and the GSE will be staggered by one or two days. Flight Unit 2 and the Spares will be shipped in a similar manner.

8.5 Packaging

8.5.1 PREPARATION FOR SHIPMENT

The PCTR components will be mounted in soft mounts in shipping containers. The packaging and marking will be in accordance with the requirements of MIL-P-007963B. Models and simulators will be mounted in similar shipping containers. A complete PCTR system will be shipped in one shipping container (batteries will be shipped separately, directly from the supplier to KSC). Packing lists will be placed inside each shipping container and a copy (in a moisture-proof bag) attached to the exterior of the container. All shipments will be made on Government Bills of Lading furnished to NASA 30 days in advance of shipment.

8.5.2 SHIPPING CONTAINER INSTRUMENTATION

The PCTR shipping container will be instrumented for recording shock loads during handling and transit. Analysis of the recorded data at the point of delivery identified when and where shock occurred and if the shocks exceeded the allowable limitations of the system.

8.6 Storage and Handling

The environment the PCTR experiences during the fabrication, storage, delivery, and installation activities will be controlled so as not to impose additional design requirements over those required for prelaunch, launch, flight and postflight operating conditions.

8.7 Manuals

Northrop will provide the manuals described in the following paragraphs in support of the program development and operations. These manuals will be updated and revised as required.

8.7.1 FAMILIARIZATION MANUAL

The Familiarization Manual will describe the complete PCTR system. Each item of equipment will be described in general terms but with sufficient detail to convey a clear understanding of the PCTR System and the operation of each item of equipment. The manual will serve as an orientation indoctrination document and as a reference document. It will be utilized by NASA to develop a training program for the astronauts and other NASA and associate contractor personnel.

8.7.2 MAINTANANCE AND REPAIR MANUAL

This manual will provide complete instructions and procedures for the maintenance and repair of PCTR equipment. Troubleshooting tables will be included to translate a malfunction from an indication to a remedial conclusion. Illustrated parts breakdown data on all PCTR elements will be included in the manual.

8.7.3 TRANSPORTATION AND HANDLING MANUAL

The manual will delineate the procedures and any special requirements for the transportation and handling of the PCTR equipment.

NSL 67-208

LOGISTICS PLAN

Section 8

CONTENTS

8.0 LOGISTICS PLAN

8.1 Introduction

8.1.1 SUPPORT REQUIREMENTS

The Logistics Plan is prepared in response to the Statement of Work (SOW), Article 1, paragraph 8, under NASA Contract NAS 8-20670. The plan covers the support requirements for the Phase Change Thermal Radiator Program in the areas of logistics, maintenance, packaging, storage, handling, and transport of models, flight articles, spares, and GSE; and delineates the procedural means, or procedures, for satisfactory accomplishment of these activities. The Northrop point of contact for the support activities covered herein lies in the Operations Group of the PCTR Program Organization (see Figure of the Management Plan, NSL 67-201). The Operations Group is responsible for providing the documentation (plans, procedures and/or manuals) and implementing the activities covered by this plan. This plan will be updated as required. Such revisions will be accomplished by furnishing revised, amended, or additional pages as appropriate.

8.1.2 SUPPORT OPERATIONS

Northrop will provide support as follows:

a. Apollo Contractor Support

b. CM Contractor Support

c. NASA PCTR Evaluation and Training

d. NASA/KSC Prelaunch Operations

e. Northrop Factory Support Operations

8.1.2.1 Apollo Contractor Support

Northrop will provide the orientation and support required to integrate the PCTR prototype into the CM at the Apollo contractor's facility. This support will include Northrop and Apollo contractor interface meetings to establish the detailed Northrop support requirements, the preparation of a detailed PCTR Logistics Plan for NASA approval, and the implementation of the Logistics Plan.

8.1.2.2 CM Contractor Support

Northrop will provide orientation and support required to support the PCTR requirements for the CM thermal/vacuum tests and the CM flight tests. This support will include Northrop and CM contractor interface meetings to establish the detailed Northrop support requirements, the preparation of a detailed PCTR Logistics Plan for NASA approval, and the implementation of the Logistics Plan.

8.1.2.3 NASA PCTR Evaluation and Training

Northrop will provide support at NASA/MSFC and/or other NASA designated locations in support of PCTR orientation, familiarization, and preliminary support planning operations. The preliminary support planning operations will serve to establish detailed Northrop support requirements to aid NASA in the accomplishment of PCTR evaluation and training requirements. The NASA activities considered in this support will include evaluation and training.

8.1.2.4 NASA/KSC Prelaunch Operations

Northrop will assist the CM contractor at NASA/KSC in support of the PCTR checkout installation, installation into CM. This support activity will take place primarily in the Mission Support Operations Building, MSOB, and will consist of a detailed visual examination of the PCTR System for physical damage and gross go-no-go checkout of the system.

Any malfunction of the PCTR will require the use of the backup flight unit.

No repairs or overhaul maintenance activities will be performed on the PCTR at NASA/KSC, except GSE.

8.1.2.5 Northrop Factory Support Operations

PCTR repairs and/or overhaul maintenance operations will be performed at the Northrop Hawthorne Factory. All such repair and/or overhaul operations will require the conduct of acceptance tests prior to return of the PCTR to NASA. Factory spares will be utilized in support of the factory repair and/or overhaul maintenance operations. Refurbishment of salvable parts will be accomplished by Northrop or the original part supplier. Parts damaged or worn beyond repair will be disposed of only upon NASA approval.

8.2 Support Criteria

The following subparagraphs describe the criteria employed in maintenance and overhaul activities for the PCTR and ancillary equipment, and the definition of terminology applied thereto.

8.2.1 EQUIPMENT MAINTANANCE AND OVERHAUL

Maintenance and overhaul will be performed to the following criteria.

a. Electrical/Electronic Equipment (either installed or on the bench) - Checkout and replacement will be at the component (black box) level. A black box is defined as a combination of factory replacement units which are contained within a physical package as an integral unit.

b. Non-electrical/Electronic Equipment (either installed or on the bench) - Checkout and replacement will be at the lowest replaceable serialized component level which includes only those components removable as integral units from the PCTR system. Bench test equipment will be used for malfunction verification of components removed from the PCTR because of suspected failure. Bench test equipment will be used for spares verification prior to installation.

c. Shelf Life - The PCTR will be capable of fulfilling its mission after being stored for five years with minimum refurbishment film and batteries. After any storage, the PCTR will be operationally checked to determine its operability level. Any malfunction, or degradation of operations noted in comparing against previous test data, will result in component replacement and/or overhaul.

d. Failure Reports - A failure report will be prepared on all failures occurring on PCTR hardware. Any failure will be reported to NASA by TWX within 24 hours after failure occurs. The report will contain a description and analysis of the failure, and corrective action taken and/or proposed.

e. On-Site Accessibility (KSC) - There will be access to the PCTR storage compartment at about five (5) days before launch for installation of the battery and liquid LN_2. All other checkout and maintenance on the PCTR will be accomplished prior to T minus forty (40) days.

f. On-Site Maintenance (KSC) - Scheduled and unscheduled maintenance on site will not be required as checkout activities on-site consist only of visual inspection and go/no-go operating checks to determine if the equipment has been damaged in transit. If damage has occurred, the item so damaged will be returned to Northrop/Hawthorne for rework, tested and reshipped, or replaced from spares on site, or from backup units. Batteries will be activated at KSC and checked with a bench test voltmeter for proper voltage level prior to installation in the PCTR.

g. Ground Support Equipment (GSE) - On-site GSE will not be required as only visual inspection and a go/no-go operating check will be performed at KSC. The go/no-go check will be made using a test battery or simulator for power.

8.3 Spares

8.3.1 PCTR SYSTEM (LESS BATTERIES)

Spares provisioning will be specified by NASA in the Statement of Work for Phase D. The second Flight Units 1 and 2, will provide one complete backup system. Upon delivery at KSC, the systems will be removed from their shipping containers and inspected, including analysis of shipping instrumentation data per Paragraph 8.5.2, for transport or handling damage. Upon satisfactory verification that no damage has occurred to either system, the first flight unit will be installed by the PCTR contractor for launch and the second flight unit either becomes primary equipment for a second launch or becomes a backup unit. In the event a system component is damaged, it will be returned to the factory for rework, test and reshipment to KSC.

8.3.2 BATTERIES

Spares provisioning for the batteries will be similar to that for the rest of the PCTR System. A minimum of three battery sets will be shipped to KSC for the two PCTR Systems delivered. Two spare batteries will be available for the first flight. If the spare for Flight Unit 1 is not used on that flight, it becomes the spare for Flight Unit 2. Disposition of the unused spares will be as directed by NASA.

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The Program Administrator will define, establish, and maintain records for the PCTR Program to assure efficient control of the equipment, flight articles and spares, GSE, and test equipment, and the flow of repairable items between Northrop and NASA sites. These records are used for determining subsequent spares requirements, provisioning and schedules.

8.3.4 DISTRIBUTION AND CONTROL

All equipments and spares delivered to NASA will be through the PCTR Operations Group. This group will maintain records as described in paragraph 8.3.3.

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Spares determined to be obsolete for the PCTR Program will be reported to NASA for disposition instructions.

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After being packaged as specified in paragraph 8.5, flight articles will be transported from Northrop/Hawthorne to KSC or MSFC. Shipment will be made by a common carrier, preferably by air freight. However, Government air transport will be utilized as directed by NASA. Routing to KSC for the two modes is as follows:

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This manual will provide complete instructions and procedures for the maintenance and repair of PCTR equipment. Troubleshooting tables will be included to translate a malfunction from an indication to a remedial conclusion. Illustrated parts breakdown data on all PCTR elements will be included in the manual.

8.7.3 TRANSPORTATION AND HANDLING MANUAL

The manual will delineate the procedures and any special requirements for the transportation and handling of the PCTR equipment.

NSL 67-210

SCHEDULE PLAN

Section 10

OVERALL TABLE OF CONTENTS

SECTION 10

SCHEDULE PLAN

The total Program Schedule is shown in Figure 10-1. Individual schedules for manufacturing, test, and other Plans are shown in these respective individual Plans.

The time estimates for the hardware development of the system are derived from the cognizant functional elements. The sequential phasing of the various time elements is based on determination of the major restraints on all activities. The depth to which these restraints are developed at the lower breakdown levels is apparent from the PERT network described in Section 1.2 to illustrate management control of schedules and costs. Also more detailed Gant charts are provided in Section 1.1 covering:

(a) Master Milestone Schedule

(b) Management and Engineering Coordination

(c) Procurement, Reliability, and Quality Control Programs

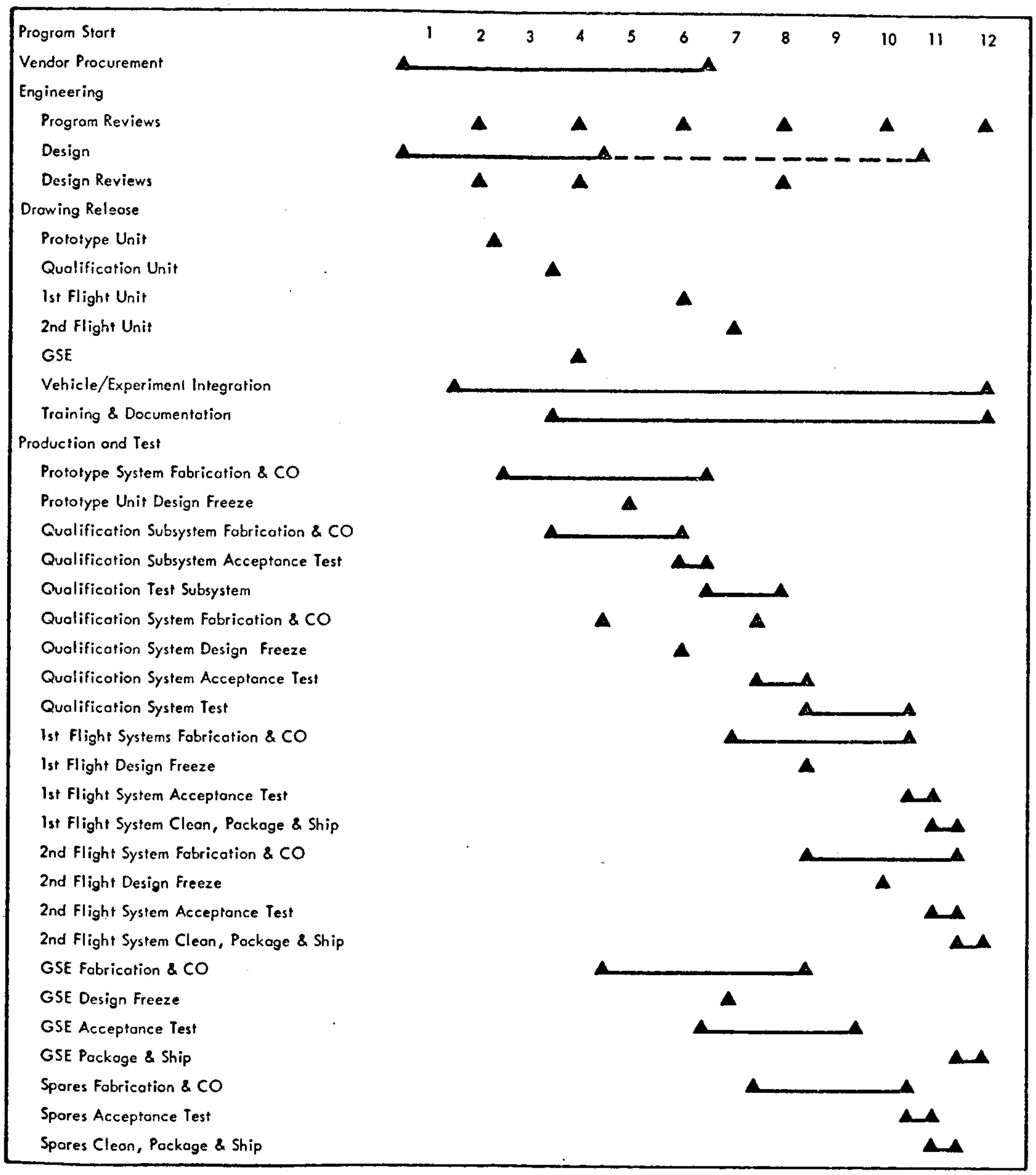

FIGURE 10-1 PHASE IV PCTR FLIGHT EXPERIMENT PROGRAM SCHEDULE

TABLE OF CONTENTS

MASTER END ITEM SPECIFICATION PLAN

CONFIGURATION CHART

SPECIFICATION ISSUE	ECP'S	PRODUCTION EFFECTIVITY

NORTHROP SYSTEMS LABORATORIES
SPECIFICATION CHANGE LOG

AS OF ____________
SUPERSEDING ______

SPECIFICATION NO.

SCN NO.	ECP NO.	SCN DATE	PAGES AFFECTED	ITEM EFFECTED

12.1 SCOPE

This Specification establishes the requirements for performance, design, test, and qualification of one type of equipment, identified as the Phase Change Thermal Radiator Flight Experiment (PCTR Flight Experiment), hereinafter referred to as the PCTR Flight Experiment. The PCTR Flight Experiment defined herein is designed to be self sustaining in regard to support functions such as power and data recording, but to be physically mounted in specific areas of both the Apollo Command Module (CM) and Service Module (SM). The PCTR Flight Experiment will evaluate the performance of selected solid to liquid phase change thermal control materials and systems while under the influence of a zero gravity environment.

12.2 APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this Specification to the extent specified herein. In the event of conflict between documents referenced here and other detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall be considered a superseding requirement.

12.2.1 System Project Documents

MC 999-0058	Approved Materials for use in the Apollo Spacecraft, General Specification for, NAA, 10/1/65
MC 414-0365	Connectors, Electrical System, Apollo, NAA, 12/27/63
MC 999-0050	General Test Requirements for Apollo Subcontractors and Suppliers, NAA 8/1/64
MC 999-0051	Apollo Environmental Design and Test Requirements, NAA, 7/31/64
MC 999-0007	General Specification, Human Engineering Design Criteria for Spacecraft Systems, dated 15 September 1962

12.2.2 Specifications

12.2.2.1 Military

MIL-T-152B	Treatment, Moisture and Fungus Resistance of Communication, Electronics and Associated Electrical Equipment, dated 24 August 1962
MIL-D-1000	Drawings, Engineering and Associated Lists, dated 1 March 1965
MIL-W-5088C	Wiring Aircraft, Installations of, dated 26 May 1965
MIL-E-6051C	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft, dated 17 June 1960
MIL-W-6858C	Welding, Resistance; Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys, Spot and Seam, dated 20 October 1964

Military (Cont)

MIL-P-007936B	Parts and Equipment, Aeronautical Preparation for Delivery, dated 19 November 1957
MIL-I-8500B	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles, dated 10 October 1960
MIL-W-8611A	Welding, Metal Arc and Gas, Steels and Corrosion and Heat Resistant Alloys, Process for, dated 24 July 1957
MIL-I-26600	Interference Control Requirements, Aeronautical Equipment, dated 2 June 1958 Amendment 2, dated 9 May 1960, Change Notice 1, dated 1 June 1962
MIL-P-55110A	Printed Wiring Boards, dated 18 December 1964, Amendment 1, dated 29 July 1965

12.2.2.2 NASA

NPC-200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components and Services, dated April 1962
NPC-200-4	Quality Measurements for Hand Soldering of Electrical Connections, dated August 1964
NPC-250-1	Reliability Program Provisions for Space System Contractors dated July 1963
NPC-500-1	Apollo Configuration Management Manual
MSC-EMI-10A	Addendum to MIL-I-26600, dated 17 October 1965
MSC-ASPO-56A	MSC Supplement to NPC 200-4, dated 1 June 1966

12.2.3 Standards

12.2.3.1 Military

MIL-STD-16C	Electrical and Electronic Reference Designators, dated 4 December 1961
MIL-STD-130B(1)	Identification Marking of U.S. Military Property, dated 7 February 1964
MIL-STD-143A	Specifications and Standards, Order of Precedence for the Selection of, dated 12 May 1963
MIL-STD-447	Definitions and Interchangeable, Substitute and Replaceable Items, dated 29 May 1959
MIL-STD-803A-1	Human Engineering Design Criteria for Aerospace Systems and Equipment, Part I, Aerospace System Ground Equipment
MS-33586A	Metals, Definition of Dissimilar, dated 16 December 1958

12.2.3.2 NASA

MSFC-STD-271	Fabrication of Welded Electronic Modules, dated 30 April 1964

12.2.4 Publications

NSL 67-201	Management Plan
NSL 67-202	Technical Integration Plan
NSL 67-203	Design Plan
NSL 67-204	Manufacturing Plan
NSL 67-205	Product Assurance Plan
NSL 67-206	Test Plan
NSL 67-207	Facilities Plan
NSL 67-208	Logistics Plan
NSL 67-209	Cost Plan
NSL 67-210	Schedule Plan
NSL 67-211	Manpower and Funding Plan
QC 500	Quality Control Requirements for Suppliers

12.2.5 Handbooks

Military

MIL-Hdbk-217	Reliability Stress and Failure Rate Data for Electronic Equipment, dated August 1962

12.3 REQUIREMENTS

12.3.1 Performance - The functional characteristics specified herein define the performance parameters for the Phase Change Thermal Radiator Flight Experiment (PCTR Flight Experiment) and establish the design within the requirements established by the primary purpose of the PCTR Flight Experiment specified herein. The PCTR Flight Experiment shall in no way impose operational constraints on the Apollo CM or SM other than those identified in the interface requirements specified in 3.2 herein. The PCTR Flight Experiment shall consist of the following:

a) Observation Unit Experiment (3.4.1)

b) Radiator Experiment (3.4.2)

c) Support Subsystems (3.4.3)

12.3.1.1 Operational Requirements - The PCTR Flight Experiment shall be designed for a zero gravity mission/use of not more than twenty hour total operating time.

12.3.1.2 Operability - Operability, or subsystem effectiveness, is the probability that the system will accomplish a specified experiment within a given period of time under the planned support and usage conditions. Reliability, maintainability, human engineering, system safety, and crew safety shall be integrated in the effectiveness program. The basic PCTR Flight Experiment effectiveness requirements shall be as defined in the following sub-paragraphs.

12.3.1.2.1 Reliability - Reliability shall be a prime consideration in the design, development, and fabrication of the subsystem equipment. When operating within the environments and conditions specified herein, the PCTR

Flight Experiment system reliability goal shall be 0.99 for the experiment described in this specification.

12.3.1.2.1.1 Reliability Program - The Contractor shall implement a reliability program in accordance with the Reliability Program Plan (NSL 67-205(2)) and with NASA Publication NPC 250-1 as specified in the plan.

12.3.1.2.2 Maintainability - The inclusion of maintainability characteristics as an inherent feature of design and installation shall occur simultaneously with initial design, and throughout the development cycle as defined in this document.

There shall be no requirement for in-use maintenance of PCTR Flight Experiment sub-systems. Maintainability design for ground operations shall enable installation, preservation and restoration of operational capability with minimum expenditure of maintenance resources including time, personnel, and material. The inclusion of maintainability characteristics as an inherent feature of design and installation shall occur simultaneously with initial design, and throughout the development cycle.

The following maintainability principles shall be applied in the design of the PCTR Flight Experiment system:

a) Minimum number and complexity of maintenance tasks

b) Optimum accessibility

c) Minimum training requirements for operating and maintenance personnel

d) Minimum tool and test equipment requirements

e) Maximum safety of personnel and equipment

12. 3.1.2.3 Useful Life - The PCTR Flight Experiment system, less battery and film, shall be designed for a mission in the space environment defined herein, after being stored for 2 years within the storage constraints described in paragraph 3.3.11 and after undergoing all checkout and launch operations.

12.3.1.2.4 Natural Environment - The PCTR Flight Experiment system shall conform to the requirements of MC 999-0051- NAA, 7/31/64

12.3.1.2.5 Transportability - Full design recognition shall be given to the durability requirements of the system during transportation, handling and pre-flight operation. The equipment shall be designed for transportation by air carrier with a minimum of protection. Special expendable packaging and fragile handling transportation techniques shall be used to prevent system penalties. Batteries shall be shipped separately from the system.

12.3.1.2.6 Human Performance - The human performance requirements of MC 999-0007 and MIL-STD-803A-1 shall be used as guides in the design of the PCTR Flight Experiment system.

12. 3.1.2.6.1 Crew Participation - Except for the EVA retrieval of the space radiator package, all experiment setup, control, and operation will be performed inside the CM with the astronaut operator dressed in a constant wear garment in shirtsleeve conditions.

12.3.1.2.6.1.1 Handles and Knobs - Handles, knobs, connectors, latches, etc. that have to be operated by the astronaut during space radiator package EVA retrieval shall be:

a) Operable wearing EV thermal gloves

b) Large with ample clearance, e.g., 1.00 - 1.25 inches in diameter with a 2.0 - 5.0 inch finger clearance for carrying handle.

12.3.1.2.6.1.2 Surface Coatings - Thermal control coatings on the radiator experiment shall not be touched except by the ambient atmosphere.

12.3.1.2.7 Safety - The design of the PCTR Flight Experiment shall not contribute to the hazard of fire, explosion, or toxicity to the crew, launch area personnel or facilities. The hazards to be avoided include the hazards of a spark on ignition sources including static electricity discharge.

12.3.1.2.7.1 Personnel Considerations - Requirements to be observed with respect to personnel safety shall be as specified herein.

12.3.1.2.7.1.1 Structural Design - The structural components shall be designed so that no malfunction shall result in a condition hazardous to the crewman.

12.3.1.2.7.1.2 Electrical Power Control - Electric power control, including emergency controls where applicable, shall be provided to the astronaut. Circuit protection shall be incorporated to preclude any PCTR Flight Experiment electrical malfunction from affecting crew safety. Requirements to be observed with respect to personnel safety shall be as specified herein:

a) The PCTR Flight Experiment shall be designed so that no single electrical malfunction during the mission shall result in a condition hazardous to the crewman.

b) Controls shall be readily identified and so positioned to prevent inadvertent operation by the crewman and shall be properly marked and identified.

12.3.1.2.7.2 Equipment Safety

12.3.1.2.7.2.1 Explosion Proofing - Where practicable, the various components shall be hermetically sealed or of explosion-proof construction.

12.3.1.2.7.2.2 Fail-Safe Design - A fail-safe design shall be provided in those areas where failure will disable the system or cause damage to equipment, injury to crew, or inadvertent operation of the equipment.

12.3.1.2.8 Induced Environment - The PCTR Flight Experiment system shall conform to the induced environment requirements of the Apollo launch vehicle.

12.3.2 Interface Requirements - Interfaces are defined for the system requirements as follows:

a) Stowage Interface per NAA, MH01-22018-414

b) Electric Energy transfer Interface per NASA, MC 414,-0365

c) Heat Flow Experiments Interface (to be defined by NASA).

12.3.3 Design and Construction

12.3.3.1 General Design Features - This section contains design considerations of a general nature that are applicable to each subsystem and to the PCTR Flight Experiment system.

12.3.3.1.1 Ultimate Factor of Safety - The ultimate factor of safety shall be not less than 1.5 applied to limit loads.

12.3.3.2 Selection of Specifications and Standards - Specification and standards shall be selected in accordance with the requirements of Standard MIL-STD-143.

12.3.3.3 Materials, Parts and Processes - The selection and application of suitable materials, parts and processes shall be in accordance with the requirements of MC 999-058. Use of materials not contained in MC 999-0058 shall require prior written approval of NASA.

12.3.3.4 Standard Commercial Parts - MS, AN, and MIL standard parts shall be used to the greatest possible extent. When such standard parts are not available, commercial parts such as screws, bolts, nuts and cotter pins, etc. may be used provided they are suitable for the purpose and can be replaced by corresponding AN, MS, or MIL parts without alteration.

12.3.3.5 Moisture and Fungus Resistance - Materials which are nutrients for fungus shall not be used whenever possible. Fungus nutrient materials may be used in hermetically sealed assemblies and other accepted uses, such as paper capacitors and treated transformers. Other necessary fungus nutrient materials will be treated in accordance with MIL-T-152 to render the exposed surface fungus resistant. Hygroscopic material shall not be used except in hermetically sealed assemblies.

12.3.3.6 Corrosion of Metal Parts - Materials shall be corrosion resistant types or shall be suitably processed to resist any corrosion effects resulting from environmental conditions specified herein. Protective coatings shall not crack, chip, peel, or scale with age when subjected to the environmental extremes specified. Oil-base lubricating compounds shall not be used. Finishing, coating, and marking materials shall conform to NASA Specification. The use of dissimilar metals in immediate contact shall be avoided whenever possible. When dissimilar metals are used in immediate contact, an interposing material shall be used. Dissimilar metals are defined in MS 33586. Where the application of dissimilar metals in direct contact or exposed to the same electrolyte cannot be avoided, suitable protection shall be provided.

12.3.3.7 Interchangeability and Replaceability - Interchangeability and replaceability, as defined in MIL-STD-447, shall be accomplished to the extent required by MIL-I-8500 and shall apply to major components at the remove and replace level; and all spares selected for logistics support. All assemblies, parts and components having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-1000.

12.3.3.8 Workmanship - Workmanship for the PCTR Flight Experiment, including sub-system parts and equipment, shall be to high quality aerospace standards with particular attention directed toward: freedom from blemishes, burrs, and sharp edges; required tolerances on dimensions; adequate and correct marking on parts; thoroughness of cleaning and welding; neatness and thoroughness of wiring installations; and satisfactory tightness and proper torque of assembly screws and bolts.

12.3.3.9 Electromagnetic Interference - The PCTR Flight Experiment and all PCTR Flight Experiment equipment shall conform to the requirements of Specification MIL-E-6051 and MIL-I-26600 as amended by MSC-EMI-10A.

12.3.3.10 Identification and Marking - The PCTR Flight Experiment and all subsystems, as applicable, components and assemblies shall be marked for identification in accordance with Standard MIL-STD-130 as follows:

Item Name

Manufacturer's Part Number

Model Designation

Model Serial Number

Manufacturer's Sequence Number

NASA Control Number

NASA Serial Number

Contract Number

12.3.3.10.1 Wiring Identification - All interconnecting electrical wiring in the PCTR Flight Experiment shall be identified in accordance with Specification MIL-W-5088.

12.3.3.10.2 Printed Circuits - Printed circuits shall be marked in accordance with Specification MIL-P-55110.

12.3.3.10.3 Reference Designation for External Equipment Connectors - All connectors mounted on the equipment which accept or mate with connectors from external interconnecting-type wiring shall be assigned a "J" number. The

Contractor shall assign these numbers numerically and consecutively, starting with J-1, for each unit of equipment. In addition, each "J" number shall be preceded by the unit number assigned the unit in accordance with Standard MIL-STD-16, "Electrical and Electronic Designations." This "J" number shall appear on each side of the panel in a visable location. Connectors may be further identified, on that side of the panel to which the mating connector attached, by a name denoting the function of that cable attached thereto.

12.3.3.10.3.1 Marking of External Connectors - Connectors that form a part of the external interconnecting wiring shall be identified by a "P" number corresponding to the "J" number of the mating unit connectors. When two cable connectors affixed to interconnecting cables are to be mated, the connector containing the coupling ring or active retention device screw, clip, etc. shall be assigned a "P" number and the mating connector shall be assigned a "J" number. Where application of reference designators in accordance with 3.3.10.3 or 3.3.10.3.1 is impracticable for reasons pertinent to loss of interchangeability of identical items and feasibility of sequential numbering, the Contractor may elect to apply reference designators in accordance with MIL-STD-16.

12.3.3.11 Storage Requirements - The PCTR Flight Experiment shall be designated for a storage period of 2 years under conditions as defined in Technical Specification, Exhibit B.

12.3.3.12 Electrical Connectors - Electrical connectors shall conform to Specification MC 414-0365. Where more than one external connector is provided, they shall be such that they cannot be interchanged. Special purpose connectors may be used upon specific application approval by MSFC. All connectors shall be keyed such that improper mating is not possible.

12.3.3.13 Welding

12.3.3.13.1 Resistance Welding - Resistance Welding (spot and seam) shall conform to Specification MIL-W-8611.

12.3.3.13.2 Structural Welding - Where applicable, structural welding shall be in accordance with MIL-W-8611.

12.3.3.14 Soldering - Soldering of all electrical connections shall be in accordance with contractor supplied and NASA approved specifications which encompass the requirements of NPC 200-4 as amended by MSC-ASPO-56A.

12.3.3.15 Welded Connections - Electrical connections shall be welded in accordance with MSFC Standard 271.

12.3.3.16 Strategic and Critical Materials - The use of strategic and critical materials shall be held to a minimum.

12.3.3.17 Special Cleanliness

12.3.3.17.1 Marking - Packages containing equipment cleaned to specification levels of cleanliness shall bear precautionary labels or markings to indicate such cleanliness.

12.3.4 Requirements of Basic Experiments

12.3.4.1 Observation Unit Experiment Requirements

12.3.4.1.1 Performance - The Observation Unit Experiment shall be capable of providing a means of study, visual and recorded, of solid-liquid interfaces during melting and freezing of selected thermal control materials under the influence of a zero gravity environment.

The Observation Unit Experiment shall be physically mounted in a specific area of the Command Module. It shall be reliant upon the PCTR Flight Experiment Support Subsystems for such support functions as power and control and data recording. This shall include the power and control of the motion picture camera, but not the actual camera.

12.3.4.1.1.1 Observation Unit Experiment Components - The Observation Unit Experiment components shall consist of the following:

a) Optical Subassembly

b) Test Cell Positioner

c) Electronics Compartment

d) Control Panel

e) Hot Test Cell Storage

f) Cold Test Cell Storage

12. 3.4.1.2 Operability - The Base Subsystem operability requirements shall be as defined in the following subparagraphs.

12.3.4.1.2.1 Reliability - Reliability shall be a prime consideration in the design, development, and fabrication of the Observation Unit Experiment. The Observation Unit Experiment shall be designed to a reliability goal of .9977 to be compatible with the PCTR Flight Experiment system reliability goal of 0.99.

12.3.4.1.2.2 Reliability Program - The reliability program defined in 3.1.2.1 shall apply to the Observation Unit Experiment Subsystem.

12.3.4.1.2.3 Maintainability - The inclusion of maintainability characteristics as an inherent feature of design and installation shall occur simultaneously with initial design, and throughout the development cycle.

12.3.4.1.2.4 Useful Life - The Observation Unit Experiment Subsystem shall be designed for a mission in the space environment defined herein, after being stored for two years in a controlled environment.

12.3.4.1.2.5 Transportability - The Observation Unit Experiment Subsystem, as part of the PCTR Flight Experiment shall be designed to be transportable by air carrier with the minimum protection specified in 3.1.2.5.

12.3.4.1.3 Design and Construction

12.3.4.1.3.1 Optical Subassembly - The Optical Subassembly shall be enclosed in a rigid cabinet which serves as the optical bench. The cabinet will support the major optical elements (tubing, camera and test cell positioner) and will be assembled with the electronic compartment to complete the experiment module located in the Apollo Rack Box Void. The Optical Subassembly shall consist of the following subassemblies and components:

a) Optics Tube and Beam Splitter
b) Illuminator
c) Lens
d) Eyepiece
e) Camera
f) Film
g) Test Cell
h) Test Cell Positioner
i) Thermocouple Assembly

12.3.4.1.3.1.1 Optics Tubing - The following optical subassembly elements are to be integrated by the optics tubing: lens, eyepiece, beam splitter, and camera. The interconnecting tubing between the lens and the camera shall be horizontal, made of aluminum and consist of three segments. Segment one shall be 0.875 x 0.745 I.D. x 2.75 long. It shall connect the lens to the center block (segment two). Segment two shall be 3.88 long x 1.125 square and connect segment one to an adjustable tube (segment three).

The adjustable tube (segment three) shall be 1.00 O.D. x .745 I.D. x 2.75 long and connects the center block to this camera. The center block shall also incorporate a beam splitter, the center of which shall be 1.500 from its lens tube connecting end. The beam splitter shall transmit 95% of the light to the camera and reflect 4% to the eyepiece. The center block shall also have provisions for attaching the lens to camera interconnecting tubing to the eyepiece. This latter connecting tubing shall be .975 O.D. x .685 I.D. x 3.25. It shall attach to the center block at 1.500 from the center block lens connect end and shall be at right ANGles to the interconnecting tubing between the lens and camera.

12.3.4.1.3.1.2 Illuminator - The Illuminator shall provide a point source of light through the backside of the test cell, which is focused midway between the test cell and objective lens and on the optical axis of the objective lens.

The Illuminator shall consist of a lamp, a lens and filter assembly, a prism and housing.

The lamp design requirements are:

Rated Power,	2 watts
Rated volts	38
Minimum Supply Voltage	200
Minimum starting voltage	1000
Rated, avg. lab. life at design volts	150 hours
Minimum light screan di.	.127 mm
Average brightness	25 candles/mm^2
Average axial candle power	.3
Bulb type	T5
Base type	Miniature 3 pin

The lens design requirements are:

12.3.4.1.3.1.3 Lens - The lens shall be of the microscope objectives. The lens design requirements are:

Focus	13.0 mm
Magnification	10 X
Tube Length	160 mm
Visual Field of View at Object	1.2 mm
Numerical Aperture	.22
% Area of Central Obstruction	17.5
Working Distance	24.0 mm
Length (from R.M.S. shoulder)	Approximately 50.7 mm
Maximum External Diameter	44.7 mm

12.3.4.1.3.1.4 Eyepiece - The eyepiece design requirements are:

Magnifying Power	5 X
Equivalent Focal Length	50 mm
Diameter of Field	14 mm
Type	Ramsden

12.3.4.1.3.1.5 Camera - The camera design requirements are:

Film 16 mm ASA standard, perforated two sides, black and white. Camera adjustable to high speed perforations (0.3000 pitch).

Film Capacity: 200 feet, on daylight loading spools.

Speed: Single frame pulsing & 1 frame every 2 seconds.

Speed Stability: $\pm 1\ 1/2\%$

Shutter Speed: 1/50 second

Shutter opening: 160°

Footage Indicator: Automatic resetting

Weight: 8 1/2 pounds (less film)

Power Requirement: 28 $\pm$ volt dc

Current Consumption: 2.7 amps for 30 miliseconds(pulse

Cut-off Switch: Heavy duty micro-switch automatically stops camera at end of film run.

Heater: Dual ac-dc heater mounted on camera mechanism plate

Timing Light: NE-2J high-brightness neon lamp

Correlation Pulse Generator: Produces an output pulse at a frequency synchronous to the camera shutter.

Lens: None, optical flat glass cover plate, sealed for hard vacuum exposure

Lens Mount: "C" Mount

Mounting Provision: Dovetail plate on camera, tapped 1/4-20 and 3/8-16 and mating mount plate.

Case: Envelope less than 8" long x 4" x 6" high sealed for hard vacuum exposure

12.3.4.1.3.1.6 Film - The film design requirements are to be defined at a later date.

12.3.4.1.3.2 Test Cell Positioner - The Test Cell Positioner shall be a moveable frame located on the optical bench.

Peltier coolers, which are used to remove or add heat to the specimen shall be mounted on both specimen tube end plates. The test specimen shall be retained on a heavy aluminum yoke.

The Yoke shall serve as a positioning device for the specimen and act as a heat sink. The heat sink capacity of the yoke shall be implemented by two fusible material heat sinks bonded to its ends, and one fusible material heat sink attached to the central bulkhead behind the yoke.

A good conductive path between the specimen and the yoke shall be assured (while still maintaining ease of specimen installation) by means of a spring loaded sliding wedge jack, lubed with silicone grease.

The specimen shall be positioned by means of axial and lateral adjustment screws. The axial adjustment shall bring the specimen into the proper focus position, and the lateral adjustment shall bring the specimen crystallization front into view of the camera and microscope. Specimen positioning shall be provided by mounting the specimen yoke on two carriages, sliding in dove tail grooves and powered by rack and screw devices.

12.3.4.1.3.3 Thermocouple Assembly - The thermocouple assembly locates and locks five (5) thermocouples on the test cell wall with a minimum pressure of 5 psi. The assembly is hinged to a post mounted on the test cell positioner and rotates 90° to facilitate loading of the test cell. The assembly is locked in position by a spring loaded pin.

12.3.4.1.3.4 Electronic Compartment - This compartment shall basically be in the form of a drawer with a flush handle and latch and slides on the side. It shall assembly with the optical cabinet to form a total volume of 29.2 cm long, 48.2 cm wide, and 20.3 cm high (11 1/2 in. x 19 in. x 8 in.). The assembly shall occupy volume "A" in one of the rack boxes in the lower equipment bay of the Apollo command module as defined on: NAA drawing MH01-12090-116 (envelope and stowage provisions).

The electronic compartment shall contain the power and data electronics other than the manual controls. The power and data receptacle(s) for the observation experiment and control panel shall be mounted on the front face of the module. Receptacles for the radiator experiment and support module shall be mounted on the back face of the module. The radiator interconnect will be by cable with the NAA provided CM connector.

12.3.4.1.3.5 Compartments - Storage, Test Cell - Two test cell storage compartments shall be built into the structure on the left side of the rear compartment: an ambient storage box (capable of housing six test cells; and a cold storage box (capable of housing two test cells. The storage compartment(s) shall provide launch and reentry shock isolation for the test cells.

12.3.4.1.3.5.1 Box-Storage, Ambient - The ambient storage box shall be rectangular in shape and shall have a hinged top, opening through the top of the module.

12.3.4.1.3.5.2 Box - Storage, Cold - It is an experiment objective to return the observation experiment sample to earth in a frozen state for post flight evaluation. The selected test materials for this study are water, octadecane and octacosane. Octacosane, melt pt 62°C, can be returned in the solid state without any special storage system. A special cold storage system will be required for the water and octadecane, melt pt 28°C, samples. The weight, volume and power requirements for the sample cold storage system will be defined during the initial design phase.

12.3.4.1.3.6 Test Cell - The test material shall be contained in a square Lucite tube .85 cm (3/8 in.) square (inside) x 1.27 cm (1/2 in) square (outside) x 2.54 cm (1.0 in.) long. Copper end caps shall be bonded to the ends of the tube to seal the tube and to conduct the heat into or out of the test material. A spring loaded piston shall be provided inside one end cap to compensate for specimen volume change with state or temperature change. A loading port and sealing screw shall be provided in the other end cap. The overall weight of the test cell shall be 6.03 cm. The contact heating and cooling ends shall be 3.175 cm O.D. The horizontal top and bottom pieces shall be of copper. Means shall be provided in the top section for thermal expansion/contraction of the test material. Receiver for the hot junction of five thermocouples shall be dimpled axially in one side of the test cell. One shall be located at the center of the length of the cell. On both sides of this, there shall be another located at a distance of .953 cm and then another located at an additional distance of .653 cm.

12.3.4.2 Radiator Experiment Requirements

12.3.4.2.1 Performance - The Radiator Experiment space and sink shall be capable of providing a means of evaluating the actual hardware performance of a Phase Change Thermal Radiator.

The Radiator Experiment module shall be located on the external mold line of the SM with the space radiator surfaces exposed to a 2π steradian view of space.

It shall be reliant upon the PCTR Flight Experiment Support Subsystems for such support functions as power and control and data recording.

12.3.4.2.1.1 Radiator Experiment Components - The Radiator Experiment shall consist of the following:

a) Radiator Experiment Module

b) Mechanical Structure

c) Liquid Nitrogen Subsystem

12.3.4.2.2 Operability - The Base Subsystem operability requirements shall be as defined in the following subparagraphs.

12.3.4.2.2.1 Reliability - Reliability shall be a prime consideration in the design, development, and fabrication of the Radiator Experiment. The Radiator Experiment shall be designed to a reliability goal of .9977 to be compatible with the PCTR Flight Experiment system reliability goal of 0.99.

12.3.4.2.2.2 Reliability Program - The reliability program defined in 3.1.2.1 shall apply to the Radiator Experiment.

12.3.4.2.2.3 Maintainability - The inclusion of maintainability characteristics as an inherent feature of design and installation shall occur simultaneously with initial design, and throughout the development cycle.

12.3.4.2.2.4 Useful Life - The Radiator Experiment Subsystem shall be designed for a mission in the space environment defined herein, after being stored for 2 years in a controlled environment.

12.3.4.2.2.5 Transportability - The Radiator Experiment Subsystem, as part of the PCTR Flight Experiment, shall be designed to be transportable by air carrier with the minimum protection specified in 3.1.2.5.

12.3.4.2.3 Design and Construction

12.3.4.2.3.1 Radiator Experiment Module - The Radiator Experiment Module shall consist of:

a) Space Radiators (PCTR and Simple)

b) Sink Radiator - Nitrogen Cold Plate

c) Data Package

12.3.4.2.3.1.1 Space Radiators (PCTR and Simple) - The PCTR Space Radiator shall incorporate the phase change material, octacosane, to increase the thermal inertia and an aluminum honeycomb core for effective heat transfer. The phase change material and honeycomb core shall be sealed in an aluminum package. The package dimensions shall be 4 x 4 x 1/2. IITRI S-13G shall be used as a surface coating. The PCTR radiator shall be thermally isolated from internal heat sources by means of aluminized mylar blankets. Four low conductivity metallic U-bolts shall support the radiator.

Two heater elements shall be located on the back side of each radiator to provide a controlled heat input to the radiator package. These heaters shall be operated separately and in series to provide three power levels (22, 39, and 55 watts).

The space radiator experiment will employ ten temperature-sensitive resistors, hereinafter referred to as thermistors, to measure the following temperatures:

Radiator	Location	No. Thermistors
PCTR	Heater	1
	Package (heater face)	2
	Radiator	2
	U-Bolt (structure end)	1
Simple	Heater	1
	Radiator	2
	U-Bolt (structure end)	1

The thermistors shall be of the nickle-iron alloy wire type, shall be made in a flat configuration, sandwiched between two layers of plastic film, and shall have an operating temperature range of -162°C to +130°C.

The aluminum honeycomb core requirements are:

Material	3003 aluminum
Cell size	.95 cm nominal (3/8 inch)
Sheet thickness	.0030 cm (.0012 inch)
Maximum sheet spacing	.060 cm (.0236 inch)
Maximum core-to-edge spacing	.15 cm (.06 inch)
Package thickness	1.27 cm (.50 inch)

All heater and temperature sensor leads shall terminate in a connector on the bottom of the frame.

The simple space radiator shall be identical to the PCTR in weight and area, but not in thickness. The simple space radiator shall be made of aluminum alloy plate, 6061-T6, and its final thickness shall be approximately 0.4. The final thickness shall be established by weighing the PCTR Radiator Container Assembly with fusible material filled and parts plugged, so that both the PCTR and simple radiators are equal in weight.

12.3.4.2.3.1.2 Sink Radiator - The sink radiator shall be identical in design to the space PCTR. The sink radiator experiment shall operate in a controlled environment to isolate the effects of gravity on the PCTR performance. The radiator shall be thermally isolated by high vacuum and reflective shielding. The heat leak through the mounting structure, four (4) low conductivity metallic U-bolts, shall be monitored. The sink radiator package along with its supporting systems, shall be mounted in the SM on the space radiator module. The heat leak from the cold plate to the case shall be minimized by thin-wall stainless mounting tube construction. The temperature and power measurement techniques shall be identical with the space PCTR with the addition of monitoring the cold plate temperature.

12.3.4.2.3.1.3 Data Package - The data package function components are described in Section 3.4.3.3.1. The data package shall be mounted on a heat sink plate. The heat sink plate shall also be the bottom cover for the space radiator module frame. Superinsulation shall be used inside the package to protect the electronics from the environment. This electronic data package shall then be enclosed by a sheet metal cover on which a quick-disconnect connector shall be mounted. The connector shall be the electrical interface tie to the service module. The data package shall be approximately 6 x 6 x 1.4 inches.

12.3.4.2.3.2 Mechanical Structure - The mechanical structure shall consist of:

a) Frame support
b) Heat shield

12.3.4.2.3.2.1 Frame Support - The space radiator frame shall be attached to the SM Sector I structure and support the radiator module and the LN2 system. Four flush type quick release cam action latches, one at each corner of the support frame will be used to mount the radiator module. The frame support shall be indexed to the SM cutout with two dowel pins.

Two military type, flush spring retracted handles shall be provided on the radiator module to facilitate experiment removal. A handhold on the support frame (flush type) which shall be exposed when the radiator cover ejects, shall be provided. This will provide the astronaut with a reaction point while he is removing the radiator module upon completion of a test.

12.3.4.2.3.2.2 Heat Shield - The heat shield shall protect the radiator experiments from excessive aerodynamic heating during launch. The maximum allowable inner wall temperature shall be 372°K (210°F) for continuous operation. A peak temperature of 395°K (250°F) is allowable for a maximum time period of 15 minutes. The heat shield shall be ejected on command from the experiment control in the CM prior to initiation of the radiator experiment.

12.3.4.2.3.2.3 Heat Shield Ejection Subsystem - The radiator experiment heat shield shall be restrained during launch, and jettisoned at the start of test by two ejector type captive release nuts, pyrotechnically actuated. Space Ordnance Systems P/N S02-10211-13 nuts with S01-193 squibs shall be considered.

12.3.4.2.3.3 Liquid Nitrogen Subsystem - The liquid nitorgen subsystem shall be mounted to a subframe which, in turn, shall be mounted to the radiator experiment structure. The radiator experiment is located on the mold line of the Apollo Service Module. The complete radiator experiment installation consists of the radiator module, support structure and LN2 system. A tentative volume for the LN2 System is 16" x 8" x 8". Actual volume and weight requirements shall be as directed by good engineering practices.

The liquid nitrogen subsystem shall be subjected to the following pre-usage storage:

a) Ground storage prior to launch - 36 hours
b) Orbit time prior to usage - - - 3 days

The liquid nitrogen subsystem shall consist of:

a) A liquid nitorgen storage tank
b) A control subsystem
c) A plumbing subsystem

12.3.4.2.3.3.1 Liquid Nitrogen Storage Tank - The basic tank design shall conform to applicable safety codes for pressure vessels. It shall contain a means for positive expulsion of the liquid nitrogen.

Its capacity shall provide for:

a) Pre-usage storage boil-off.

b) Usage flow rate of approximately 0.35 lb./hr. for 8 hours

The back pressure is that extablished by approximately 2 feet of 1/8 inch O.D. tubing connecting to approximately 28 inches of 1/16 inch I.D. tubing, which discharges to a vacuum of less than -10^{-5} mm HG. Supply line from LN2 system to experiment shall be furnished by Northrop.

12.3.4.2.3.3.2 Control Subsystem - The control subsystem shall be capable of "on-off" type operation during check-out and "on" type only during the experiment mode. The activating signal shall be 28 volts DC. All electrical requirements shall be through one electrical connector.

12.3.4.2.3.3.3 Plumbing Subsystem - The Plumbing Subsystem shall, as a minimum, incorporate:

a) An inlet valve permitting ready filling and capping with the system installed in the SM and the spacecraft on the launch pad.

b) An overpressure relief valve and a blowout plug to prevent excessive high pressure conditions.

c) Electrical activated outlet valve.

12.3.4.3 Support Subsystems Requirements

12.3.4.3.1 Performance - The support subsystems shall be capable of supplying such PCTR Flight Experiment support functions as power and control and data recording.

12.3.4.3.1.1 Support Subsystems Components - The support subsystems shall consist of the following:

a) Data Subsystem

b) Power and Control Subsystem

c) Wiring Interconnect and Control Panel

12.3.4.3.2 Operability - The Base Subsystem operability requirements shall be as defined in the following subparagraphs.

12.3.4.3.2.1 Reliability - Reliability shall be a prime consideration in the design, development, and fabrication of the Observation Unit Experiment. The Observation Unit Experiment shall be designed to a reliability goal of .9977 to be compatible with the PCTR Flight Experiment system reliability goal of 0.99.

12.3.4.3.2.2 Reliability Program - The reliability program defined in 12.3.2.1 shall apply to the Observation Unit Experiment Subsystem.

12.3.4.3.2.3 Maintainability - The inclusion of maintainability characteristics as an inherent feature of design and installation shall occur simultaneously with initial design, and throughout the development cycle.

12.3.4.3.2.4 Useful Life - The Observation Unit Experiment Subsystem shall be designed for a mission in the space environment defined herein, after being stored for two years in a controlled environment.

12.3.4.3.2.5 Transportability - The Observation Unit Experiment Subsystem, as part of the PCTR Flight Experiment shall be designed to be transportable by air carrier with the minimum protection specified in 12.3.1.2.5.

12.3.4.3.3 Design and Construction

12.3.4.3.3.1 Data Subsystem

12.3.4.3.3.1.1 General Description - The data subsystem shall be essentially a low data rate PCM system which is recorded on magnetic tape in serial form. The basic characteristics shall be:

Bit rate	512 pps
Word rate	64 wps
Word length	8 bits
Frame length	16 words

The system shall have two frame rates: 1.88 frames per minute during the PCTR experiment, and 15 frames per minute during the observation experiments.

The electronics shall be located in 4 separate packages:

1. Programmer, which includes system clock, A-D converter, multiplexer control, record control, time code generator and shift register.
2. Radiator Experiments (Space & Sink) Multiplexers, signal conditioner amplifiers and heater controls. This package is located in the SM with the radiator experiment module.
3. Observation unit multiplexer and signal conditioning amplifiers.
4. Tape recorder head selector switch and forward-reverse tape controls.

In general, each unit shall be constructed using cord wood type welded modules. The potted module size shall be a one-inch cube with solder terminals on one surface and 4-40 inserts molded into the opposite surface for securing the module to the chassis.

There shall be sufficient test points to check out the operation of the digital sections of the data system using the ground support equipment.

12.3.4.3.3.2 Power and Control Subsystems

12.3.4.3.3.2.1 General Description - Power for the PCTR experiment shall be obtained from two primary silver-zinc batteries. A +28 volt, 1200 watt hour battery and a -24 volt, 20 watt hour battery. The +28 volt battery shall serve as the power source for the observation unit temperature control devices, the camera and light source, relays, the radiator experiment heaters, the tape recorder, and the positive regulated voltages. Approximately 500 watt hours are available for the test cell cold storage system. The -24 volt battery shall be used for the negative regulated voltages.

The regulated power requirements shall be as follows:

+24.0 ± 1.2 VDC at .15 amps

+12.00 ± .24 VDC at .2 amps

+10.000 ± .025 VDC at 0 to 25 milliamps

+4.50 ± .09 VDC at .7 amps

-6.00 ± .06 VDC at .2 amps

-12.00 ± .24 VDC at .25 amps

The 4.50 ± .09 VDC supply shall be a switching mode type regulator in order to reduce the losses from the large current and big change in voltage.

The -10.000 ± .025 VDC shall be for reference purposes and shall absorb current from the circuits which are clamped by it. It will be controlled by a temperature coefficient zenner diode circuit.

The rest of the voltages shall be obtained by series regulation since they require less of a voltage drop at relatively small current.

There shall be two identical temperature controllers, one for each end of the sample. The cooling and heating shall be accomplished by thermoelectric devices. A separate heat sink shall be provided for the hot junction at each end which shall keep the sink temperature below 43°C. At the maximum 7 amp current the thermoelectric device shall remove 1/2 watt from the sample at -23°C to the 43°C sink. The electronics shall be designed to achieve this although it might only be required for the maximum super-cooling of the water test sample.

The output of the controller shall be a variable width pulse at a frequency of approximately 7000 pulses per second. The full battery voltage shall be applied to an inductor in series with the output during the on-pulse width. During the off portion the energy stored in the inductor shall maintain the load current through a diode path from ground. Two 580 uf capacitors in parallel shall smooth the output.

The controller output shall current in one direction at a time depending on the selector switch position. However, should current be required in either direction because of the ambient conditions, a small current in the heating direction shall be supplied from the negative battery (-24v). The small current thus supplied shall cause a bias in the controller circuit during cooling but shall not present an additional load to the thermoelectric device.

12.3.4.3.3.3 Wiring Interconnect and Control Panel

12.3.4.3.3.3.1 General Description

The Wiring Interconnect will provide the hard line interconnect between the ship's cabling (CM & SM) and the three emperiment modules. The control panel shall interconnect the wiring for the total PCTR flight experiment. The control panel shall be comprised of several switches, indicator lamps, and a display meter. These switches shall include the following:

a) An off-on toggle switch for system power.

b) A pushbutton type START switch which will initiate the start of an experiment run and data recording. This switch shall have a built-in indicator lamp to indicate that the data system is on.

c) A pushbutton switch, Heater Control Override, which shall remove heater power in the event the heater controller has not switched off heater power after the prescribed temperature of the PCTR is attained. This switch shall also contain a lamp which shall indicate heaterpower on.

d) A pushbutton type switch with a protective guard to prevent inadvertent switching shall be the STOP switch and shall be used to terminate observation unit runs and to abort any experiment runs, if necessary, for whatever reason.

e) A three-position rotary switch shall select Space PCTR, Sink PCTR, or Observation unit. This switch shall enable the proper multiplexer and heater control circuits, select data frame rate, and connect proper signal conditioning amplifiers to display meter.

f) A four-position rotary switch shall set up the test condition.

g) A five-position rotary switch that shall control the operating mode of the thermo electric coolers.

h) A switch to activate the radiator experiment heat shield ejection squibs.

i) A switch to activate the LN2 system.

The panel shall also contain a record light which shall blink on for a period of 375 milliseconds during the record cycle to indicate a data frame.

12.3.4.4 Training Equipment - The prototype unit shall be used as training equipment. This equipment shall not be required to meet the flight environments specified herein.

12.3.4.5 Ground Support Equipment - Ground Support Equipment (GSE) shall consist of:

a) Liquid Nitrogen Fill System

b) Experiment Check-Out System

c) Battery Check-Out and Installation Equipment

These items of GSE shall be furnished for use in the MSOB at Kennedy Space Flight Center.

12.4 QUALITY ASSURANCE PROVISIONS

This section prescribes general reliability and quality assurance requirements for PCTR Flight Experiment system. The PCTR Flight Experiment quality assurance program shall be in general accordance with the requirements of NPC 200-3 and NSL 67-205. The qualification testing shall be implemented by means of a qualification test plan (NSL 67-206) prepared by Northrop Space Laboratories and approved by NASA.

Provisions for formal verification of the performance/design and construction requirements of the individual subsystems and componenets within the system shall correspond to the verification categories defined herein.

12.4.1 Program Elements

The program management requirements defined herein shall be met by the supplier.

12.4.1.1 Quality Control - Suppliers shall conform to the requirements of Northrop Quality Control Specification QC 500, Applicability Index 4.

12.4.1.2 Reliability Control - Reliability control of suppliers shall be in accordance with Northrop Systems Laboratories' Program Plan and as specified herein. At the completion of planned milestone dates, the following documents shall be submitted to Northrop.

a) Reliability Program Plan

b) Failure Report Status Summaries (as required)

c) Reliability Allocation (as part of the Reliability Program Plan and as updated).

d) Reliability Prediction Report Including Parts Application Data Sheets (PADS)

e) Failure Mode, Effect, and Criticality Analysis Report

f) Acceptable Parts and Materials List

g) Design Review Reports

h) Qualification Status Report

i) Reliability Assessment Report

Suppliers which are noted as non-significant shall, as a minimum, provide the following information:

a) Reliability Prediction in accordance with MIL HDBK 217

b) Failure Report Summaries and Status

c) Failure Mode, Effect, and Criticality Analyses

d) Acceptable Parts and Material List

e) Design Review Reports

f) Qualification Status List

g) Reliability Assessment Report

12.4.1.3 <u>Program Reviews</u> - The customer (NSL and/or NASA) may periodically review the reliability program with the supplier to assess its progress and effectiveness. The frequency and schedule of these reviews shall be specified by the customer but shall not interfere with the end item delivery schedule.

12.4.1.4 <u>Procurement Sources Control</u> - The supplier shall require reliability audit authority by NSL and NASA as well as himself. The supplier shall impose appropriate reliability requirements on his procurement sources to assure fulfillment of the reliability goals detailed in this document and the equipment specification.

12.4.2 Reliability Engineering

The following reliability engineering activities shall be performed by ~~the supplier:~~

12.4.2.1 A reliability prediction of the equipment shall be submitted with the proposal and shall be updated at intervals not greater than three months for the duration of the program. The prediction techniques, application methods, and failure rates of MIL-DHBK-217 may be used for this estimate but should be augmented to the maximum extent possible by documented field performance of in-house data on identical or similar operational conditions. All part failure rates shall be documented on part application data sheets for submittal to NSL. These data shall be verified during engineering and qualification test.

12.4.2.2 Failure Mode, Effect, and Criticality Analyses (FMECA) - The contractor shall generate an FMECA on all equipment to isolate and eliminate critical failure modes and identify and eliminate single point failures. These analyses shall be used in the development and analysis of qualification and acceptance tests. The results of the analyses shall be submitted to Northrop Space Laboratories for review and concurrence.

12.4.2.3 Design Review - Formal design reviews shall be held for the equipment to be delivered. All pertinent design factors, particularly the reliability, shall be critically audited. The quantity and schedule of these reviews shall be included in the proposal. Northrop Space Laboratories shall be notified twenty days before a review is scheduled. The notice shall include the date, time, location and description of the segment to be reviewed. Northrop Space Laboratories and NASA personnel may attend and participate in these reviews but the review will be conducted by the supplier. Reports of the reviews shall be prepared by the supplier and copies provided to Northrop Space Laboratories ~~within 20 days from the time of the review.~~ The report shall include a list of attendees and their organizational affiliation, a descriptive list of the actions to be taken, and responsibility for the action. Additional reports shall be submitted each month until all action items have been closed.

12.4.2.4 Failure Reporting and Correction - A control system as described in paragraph 3.7 of NASA NPC 250-1 shall be employed to report, analyze, corect and provide data feedback of all failures occurring throughout fabrication, handling, testing, checkout, and operation of the equipment. Failure analysis reports of qualification tests and end item acceptance test failures shall be approved by Northrop Space Laboratories.

12.4.2.5 Design Practices - Standard design practices used by the supplier shall be reviewed by Northrop Space Laboratories for compatibility with reliability practices. Particular elements of interest are:

a) Process Specifications
b) Fabrication, Assembly and Machining Practices
c) Drafting Practice and Drawing Specifications
d) Procedures for Formalization of "Quick Fixes" into Drawings and Specifications

12.4.3 Testing

The inspection and testing of the equipment shall be classified as follows:

a) Qualification Tests
b) Acceptance Tests

12.4.3.1 Qualification Tests - These tests shall be performed to verify the inherent capability of the design to meet the performance and environmental requirements listed in this specification.

12.4.3.1.1 Test Specimen - One specimen of the equipment shall be subjected to the qualification tests. This specimen shall be produced using the same materials and tooling processes, and under the same conditions as flight equipment.

12.4.3.1.2 Test Applicability - The qualification tests required for a particular piece of equipment shall be listed in the Test Plan, NSL 67-206. The tests so listed shall be regarded as minimum criteria; Northrop Space Laboratories may perform additional qualification tests for any of the requirements of Section 3 of this specification.

12.4.3.1.3 Test Procedures - Test procedures shall be approved by Northrop Systems Laboratories prior to the start of qualification testing. The procedure shall contain not less than:

a) Complete identification of test article
b) Description of functional requirements
c) Description of testing equipment
d) Listing of test operator functions
e) Criteria for fail/pass
f) Listing of data to be obtained
g) Disposition of test articles

12.4.3.1.4 Test Waiver - Laboratory testing of the equipment may be waived if it is demonstrated by either analysis or similarity that the equipment possesses the required characteristics.

12.4.3.1.4.1 Qualification by Similarity - Hardware that has been qualified for other space programs may be qualified for this program without qualification testing, provided each of the following conditions are satisfied.

a) The unit shall have been successfully qualified for an equal or more severe environmental test level and duration, and unit operation during such exposure shall have been equal to or more severe than the operation conditions imposed by this specification.
b) Test data for prior qualification tests shall be readily available and shall be sufficient in content and detail results of all testing conducted on each unit.
c) There are no changes in the following:
    1) Design and specifications including operating limits, weight, dimensions, materials, performance and tolerances, reliability, and quality;
    2) Fabrication methods;
    3) Inspection techniques;
    4) Manufacturing environment and tests up to the point where qualification tests would be normally initiated;

5) Electromagnetic interference.

d) Present items are from the same manufacturing continuous built lot as the qualified item.

e) Present items are interchangeable with qualified items. All available information regarding prior design, manufacturing, qualification, and usage history, as required by items 1) thru 5), shall be available for review by NSL for compliance.

When a specific unit has been successfully qualified previously to some, but not all of the environmental tests required by the Test Plan those tests necessary to complete all qualification requirements of the specification shall be defined and conducted within this program as a supplement to the prior qualification. Such testing shall be governed by the controls and documentation requirements as specified herein.

The necessary data to substantiate qualification by similarity shall be provided to NSL for review and concurrence as part of the contractor's proposal.

12.4.3.1.4.2 Qualification by Analysis - Analysis may be used in lieu of testing to qualify an article where the analytical techniques are consistent with good engineering practice, the nature of the environment is well defined, and a significantly large safety factor provides for both a reasonable margin of error and a reasonable deviation in the tolerance of the article to the environment. Analysis may be employed to establish the resistance of an article to its environment, or to show that the environment has been sufficiently reduced to eliminate it from further consideration.

12.4.3.1.4.3 Test Waiver Request - When a test or tests can be waived, the supplier will submit a request for waiver which contains the following information:

a) Complete description of similar items including photographs, drawings and performance data.

b) Test reports and test data describing previously conducted functional and environmental tests on actual or similar equipment.

c) A detailed comparison between the proposed article and the item for which similarity is claimed, listing sufficient reasons and justification to establish the validity of the similarity requests.

12.4.3.1.5 Inspection - The initial phase of testing on any article shall be the verification of the requirements of section 3 herein.

12.4.3.1.6 Environmental Tests - The environmental tests required by the equipment specification, if not waived per paragraph 12.4.3.1.4 herein, shall be conducted in accordance with the Test Plan, NSL 67-206.

12.4.3.1.6.1 Functional Check - Prior to conducting any of the specified tests, the equipment shall be subjected to three operational test cycles under ambient conditions and a record made of all parameters. These data shall provide the criteria for comparing performance of the equipment during or after environmental tests. Deterioration or change in performance of any components which could in any manner prevent the equipment from meeting functional, maintenance, reliability or service requirements during service life shall provide reason to consider the equipment as having failed to comply with the conditions of the test to which it was subjected. A record shall be kept of accumulated equipment operating time (and/or cycles) during all environmental tests and associated functional checks.

12.4.3.2 Acceptance Test - These tests are performed to verify the conformance of all flight hardware to the performance requirements. These tests shall be in accordance with NSL 67-204, Manufacturing Plan.

12.4.3.2.1 Sample Size - The tests shall be performed on 100% of the items to be delivered.

12.4.3.2.2 Test Procedure - A detailed test procedure shall be prepared by Northrop Space Laboratories and approved by NASA prior to acceptance testing or shipment of any equipment.

12.4.3.2.3 Inspection - The initial phase of each acceptance test shall be the verification of the requirements of section 3 of this specification.

12.4.3.2.4 Functional Test - A functional test shall be performed and a record made of all parameters.

12.4.3.2.5 Test Reporting - A report showing all identification data and the records developed during the inspection and functional tests of paragraphs 12.4.3.2.3 and 12.4.3.2.4 shall be provided for each unit delivered.

12.4.3.2.6 End Item Inspection Schedule Notification - Provisions shall be made for the notification of NASA of scheduled end item inspection and final acceptance testing of items defined in this document.

Notification shall be made a minimum of 72 hours (three working days) in advance of final acceptance testing to allow for NASA source inspection as required.

12.5 PREPARATION FOR DELIVERY

12.5.1 Preservation and Packaging - The preservation and packaging process used shall be the minimum that will afford adequate protection during normal handling, transit, and storage. Preparation for shipment shall be in accordance with MIL-P-7936 and as defined by the contractor and approved by NASA.

12.6 NOTES

12.6.1 Supplemental Information - Not Required

12.6.2 Deviations to Applicable Documents - The deviations to applicable documents defined herein established the extent of compliance applied to performance/design and qualification requirements specified for the PCTR Flight Experiment system.

12.6.2.1 NPC 500-1, MSC Supplement No. 1, Rev. B

Reference:	Forward
Requirements:	This specification must be prepared in general accordance with the requirements of Exhibit II of NPC 500-1.
a. Deviation:	Delete the format requirement of Paragraph 6.3 of Exhibit II to include the total number of pages of each page.
Reason:	From a maintenance and cost standpoint, the specification should not be required to have each page number changed when a page is added.

b. Deviation: Delete the format requirement of Paragraph 6.3 of Exhibit II to number pages with Part I and Part II indications.

Reason: Part II specifications are not applicable technical specifications.

c. Deviation: Delete the format requirement of Paragraph 6.3 of Exhibit II to carry release date on each page of specification.

Reason: Release dates will be included on the cover page.

12.6.3 Definitions

12.6.3.1 Constraint - A limit or the means for limiting an activity, to be further understood as a forcing function to assure that the limit is attained.

12.6.3.2 Subsystem - A functional unit comprised of components and parts having a common purpose on a large scale.

12.6.3.3 Limit Load - Limit load is the maximum anticipated load or combination of loads which a structure may be expected to experience during the performance of specified missions in specified environments.

12.6.3.4 Ultimate Load - Ultimate load is the maximum load for which the structure is designed. It is obtained by multiplying the limit load by the ultimate factor of safety.

12.10 APPENDIX (NOT REQUIRED)